**Maine State Library**
**Maine State Documents**

Forest Service Documents | Agriculture, Conservation and Forestry

9-1998

# Timber Supply Outlook for Maine: 1995- 2045

Maine Department of Agriculture, Conservation and Forestry

Maine Department of Conservation

Maine Forest Service

Charles J. Gadzik
*Maine Forest Service*

James H. Blanck
*Maine Forest Service*

***See next page for additional authors***

Follow this and additional works at: http://statedocs.maine.gov/for_docs

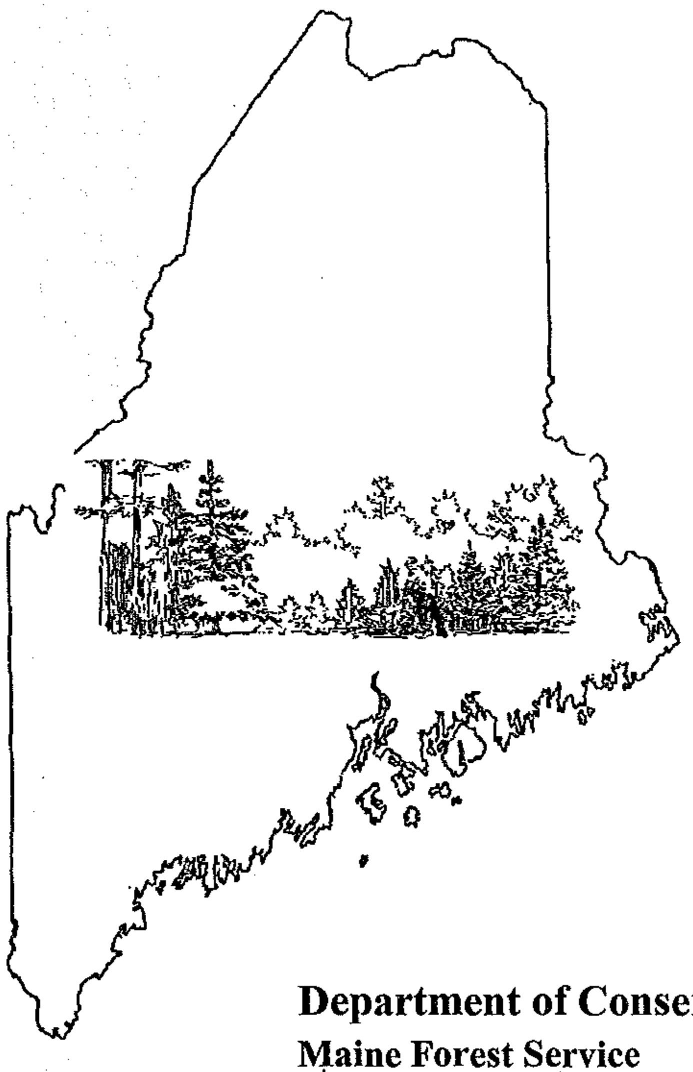
Recommended Citation
Maine Department of Agriculture, Conservation and Forestry; Maine Department of Conservation; Maine Forest Service; Gadzik, Charles J.; Blanck, James H.; and Caldwell, Lawrence E., "Timber Supply Outlook for Maine: 1995- 2045" (1998). *Forest Service Documents.* Paper 28.
http://statedocs.maine.gov/for_docs/28

This Document is brought to you for free and open access by the Agriculture, Conservation and Forestry at Maine State Documents. It has been accepted for inclusion in Forest Service Documents by an authorized administrator of Maine State Documents. For more information, please contact statedocs@maine.gov.

**Agency and/or Author**
Maine Department of Agriculture, Conservation and Forestry; Maine Department of Conservation; Maine Forest Service; Charles J. Gadzik; James H. Blanck; and Lawrence E. Caldwell

This document is available at Maine State Documents: http://statedocs.maine.gov/for_docs/28

# Timber Supply Outlook for Maine: 1995 - 2045



**Department of Conservation**
**Maine Forest Service**
22 State House Station
Augusta, Maine 04333

Charles J. Gadzik, James H. Blanck and Lawrence E. Caldwell

September 1998

ACKNOWLEDGEMENTS

This project was funded by the USDA Forest Service - State and Private Forestry - Northeast Experiment Station, Global Change Research Program, Radnor, PA.

Project co-leaders were Charles Gadzik, Director of the Maine Forest Service and Richard Birdsey of the USDA Forest Service, Northeast Experiment Station, Global Change Research Program. Principal analysts for the project were Robert Turner, R. J. Turner Company, Bristol, Vt., Lawrence E. Caldwell, formerly Senior Planner with the Maine Forest Service, and James Blanck, Chief Planner, Maine Forest Service.

The authors wish to recognize the significant contributions made by the technical review team throughout the project. Members of the technical review team were: Jeffrey Gove and Paul Sendak, of the USDA Forest Service, Northeast Experiment Station, Durham, N.H., Robert Seymour of the College of Natural Sciences, Forestry and Agriculture - University of Maine, Peter Triandafillou of J. M. Huber Resources, Ken Laustsen of Great Northern/Bowater, Will McWilliams of the USDA Forest Service, Northeast Experiment Station, Forest Inventory and Analysis Unit, MaryEllen Chilelli of the Maine Department of Inland Fisheries and Wildlife, David Edson of J. W. Sewall Company, Rob Bryan of Maine Audubon Society, John Kolenik of Seven Islands Land Company, Gordon Mott - forester in private practice. Tom Brann of the College of Natural Sciences, Forestry and Agriculture - University of Maine, and Dale Solomon of the USDA Forest Service, Northeast Experiment Station, Durham, N.H. provided valuable technical assistance in integrating forest inventory data with the computer simulation tools. Tom Frieswick, Carol Alerich and Stan Arndt of the USDA Forest Service, Northeast Experiment Station, Forest Inventory and Analysis Unit also lent considerable assistance in understanding and using the forest inventory data.

The authors also wish to thank the following, who provided a valuable peer review of the draft report: Bill Leak of the USDA Forest Service, Northeast Experiment Station, Ralph Nyland of the College of Environmental Science and Forestry - State University of New York, Paul Van Deusen of the National Council of the Paper Industry for Air and Stream Improvement, Lloyd Irland of the Irland Group, David Boulter and Jill Ippoliti of the Maine State Legislature - Office of Policy and Legal Analysis, John Scrivani of the Virginia Department of Forestry, Charles Colgan of the Edmund S. Muskie School of Public Service - University of Southern Maine, Jensen Bissell of Baxter State Park, Steve Prisley of Westvaco Corporation, Phillip Malerba and Steven Kleinschmidt of Champion International Corporation, Kevin Topolinski of Fraser Papers, Maxwell L. McCormack, Jr. of Deer Isle, Maine, and Carl Haag of Winslow, Maine.

# TABLE OF CONTENTS

# Timber Supply Outlook for Maine: 1995-2045

## Executive Summary

The Department of Conservation - Maine Forest Service, in cooperation with the USDA Forest Service, has conducted an analysis of future timber supply from Maine forest lands. This analysis utilizes the most recent statewide forest inventory of Maine (completed in December 1995) and computer models to simulate forest growth, harvest levels, and silvicultural practices. The analysis conducts a series of timber supply projections. The results of each projection are examined for long-term balance between growth and harvest. This analysis provides an overall assessment of future timber supply in Maine. It does not address every detailed question of forest management, forest health, and forest productivity.

Both the data and procedures used in this analysis include margins of error that affect the results. However, this report is intended to represent the most accurate overall assessment possible. The analysis is considered a solid baseline assessment of future timber supply. However, it must be regarded as a first step in an ongoing evaluation that incrementally improves through the collection of new data and refined analyses.

This report is a technical assessment of future wood supply, not a discussion of forest policy implications or actions. It is intended that this assessment will substantially aid the development of forestry sustainability standards for timber supply as directed by the 118th Maine Legislature, 12MRSA § 8876-A in April of 1998. The policy implications of this analysis will be discussed in the coming months and presented to the 119th Maine Legislature in 1999.

**<u>Summary of Timber Supply Projections</u>**

- The first analysis is a 50 year timber supply projection that evaluates the consequences of current management and harvest activities on Maine's 17 million acres of forest land. While inventory levels remain adequate to support current harvest levels for the entire forecast period, a continued imbalance between growth and harvest is not considered sustainable. The report concludes that current management is capable of sustaining 86% of current harvest levels. The report also identifies that substantial growth increases can be obtained with incremental improvements in overall forest management activities.

- The second analysis identifies one possible scenario of improved forest management activities that achieves a sustainable balance between growth and 100% of current harvest levels by:
    1. Increasing forest growth through improved partial harvesting techniques,
    2. Increasing the number of acres under high-yield silvicultural practices to a cumulative total of 9% of Maine's forest land by the year 2015.

In order to realize improvements in productivity, the above activities should be aggressively pursued over the next two decades.

- The third timber supply projection repeats the procedures of the first two projections for two separate ownership size classes - landowners owning 100,000 acres or more and all other landowners (53% and 47% of Maine's total forested acres, respectively). The report concludes that harvest rates for both landowner groups are higher than current management practices can sustain, with the large landowners representing the majority of the deficit. **(Note: These results represent an overall averaging of many different landowners and do not accurately represent the status of any individual landowner.)** The improved yield scenario for each landowner group demonstrates that the identified improvements in silvicultural practices can result in a long-term balance between growth and current harvest levels.

## Conclusion

The current rate of growth in Maine's forests cannot sustain indefinitely the current level of timber harvest. However, Maine's forests have a growth potential that has not been fully realized. With investments in intensive silviculture and improved management of Maine's natural forest stands, we are capable of fully sustaining the current harvest level. Activities to improve forest productivity need to be broadly implemented over the next two decades.

# Timber Supply Outlook for Maine: 1995-2045

## *I. INTRODUCTION*

The purpose of this report is to identify future trends in available wood supply from Maine's forests. This report combines the best available public information about the forest with comprehensive analytical tools (computer simulation models) to develop a series of projections of future wood availability. Both the data and the analytical tools include margins of error, this report is intended to present the most accurate overall assessment possible. This analysis is considered a solid baseline assessment of future timber supply. However, it must be regarded as a first step in an ongoing evaluation that incrementally improves through the collection of new data and refined analyses.

While recognizing the many diverse values provided by Maine's forests, the scope of this report only addresses the issue of future wood supply. The analytical techniques used in this analysis will be an important part of assessing other forest attributes such as wildlife habitat, forest health and other non-timber issues. This report is not intended to be a discussion of forest policy, but rather a report on the status of forest growth and harvest activity. The results of this analysis provide a basis for continued work to address statewide standards of forest sustainability, as directed by the 118th Maine Legislature in 1998.

The 1996 release of the fourth USDA Forest Service statewide forest inventory (Griffith and Alerich 1996) led to the logical question - What do the data mean for long-term future wood supply? In response, a cooperative project between the Department of Conservation, Maine Forest Service and USDA Forest Service was established in October 1996 to conduct a comprehensive timber supply projection and analysis. The cooperative project was staffed with personnel from both agencies and guided by a technical review team (Appendix A).

This report is an important step in answering questions about the future Maine forest. More detailed questions will be addressed in ongoing work and future reports. The Maine Forest Service will continue to collect new data on the condition of Maine's forest through an annual inventory program in cooperation with the USDA Forest Service starting in 1999.

This report is partial fulfillment of legislation passed in the spring of 1998 by the 118th Maine Legislature 12 MRSA § 8877-A, sub-§3 Timber supply modeling (P.L. 1997, C. 720 Sec. 11).

## *II. MAINE'S TIMBER RESOURCES - background summary*

The supply of timber from Maine's forests is influenced by many factors, including the amount of forest land, the distribution of different forest cover types, the volume of standing

inventory, and rates of growth and removal. These forest statistics are integral components of the timber supply simulation model used in this analysis, and have been extensively measured and are well documented in four forest inventories conducted by the USDA Forest Service in Maine in 1959, 1972, 1982 and 1995. A background summary of relevant forest statistics for Maine follows.

## A. ACREAGE

Maine has approximately 17.7 million forested acres, about 90% of the state's total land area (Griffith and Alerich 1996). Though there have been changes of use on individual acres, the total area in forest land has remained relatively constant since the 1960's Gains and losses in forest land are roughly equal - abandoned agricultural lands reverting to forest lands are balanced with losses of timberland to residential or commercial development.

Approximately 95% of Maine's forest land (16.9 million acres) is classified as commercial timberland; that is, acreage with the productive capacity to grow timber and is available for timber utilization. The amount of commercial timberland also has been relatively stable over the last 40 years. How much acreage is removed from the commercial timberland base by regulatory restrictions, landowner attitudes toward timber harvesting, and conflicts between timber harvesting and other land uses is not easily measured and is subject to debate. These issues are further discussed in Section III. C. 1. - Acres available for harvest.

## B. INVENTORY

The forest inventory represents the potential supply available for harvest and utilization. Economic and biological constraints may prevent portions of the inventory from being available as supply, but supply and inventory are treated as equal in this report. The timber inventory of commercially useable trees (growing stock volume), currently estimated to be 21.9 billion cubic feet, has fluctuated substantially since the first estimates early in this century (Figure 1.)

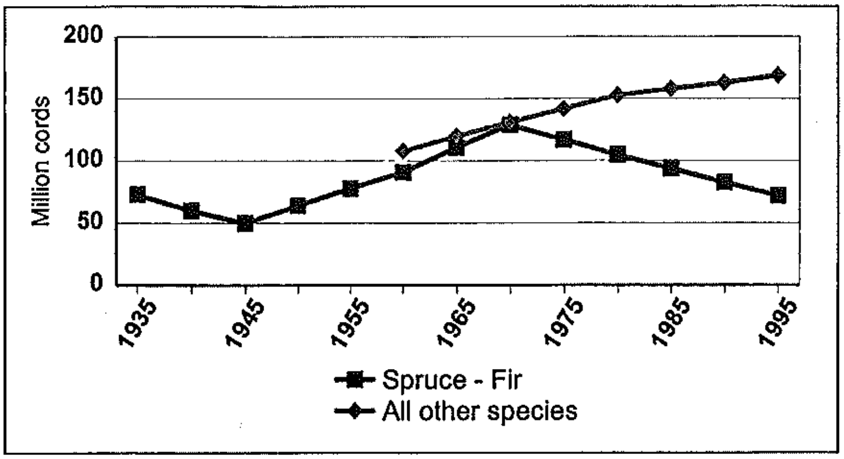



**Figure 1. Estimates of Maine's Growing Stock Volume, 1935 to 1995.**
(Irland 1996, Ferguson and Longwood 1960, Powell and Dickson 1984, Griffith and Alerich 1996.)

The profile of acres at various stages of growth is referred to as the age-class structure of the forest. All four forest inventories in Maine (1959, 1972, 1982, 1995) document an unbalanced age-class structure (Figure 2). Principal reasons for this imbalance are spruce budworm outbreaks of 1909 to 1929 and 1972 to 1986 (Webb, Blais and Nash 1961, and E.G. Kettela 1983), periods of concentrated harvest activity, and episodes of abandonment of agricultural lands.

A managed forest with a balanced age-class structure would have equal number of acres in each age class, and an equal number of acres would reach maturity every year. While it is intuitive that simply harvesting net growth should result in a stable inventory, Maine's age-class structure prevents such an outcome. The natural forces that created Maine's forest structure over many decades realistically prevent a management program from achieving a perfectly balanced age-class structure. However, the advantage of a stable inventory that results from having a forest with an equal number of acres in each age-class justifies pursuit of the goal. In a discussion of inventory trends it is helpful to estimate, as a theoretical ideal, what inventory level would result if a balanced age-class forest was achieved. Appendix E discusses one analytic approach for determining this theoretically ideal inventory. The estimated inventory level identified is between 15 and 20 billion cubic feet. The key point is that this idealized inventory is less than the peak inventory measured in 1982 and more than was estimated during the 1930's.

In 1982 young stands (seedling/sapling) occupied 18% (3.0 million acres) of Maine's forest; in 1995 25% (4.2 million acres) of Maine's forest were in this size class (Figure 2).

This change to a younger forest is most pronounced in the spruce and fir forest types and accounts for much of the decline in spruce and fir inventory since 1971.

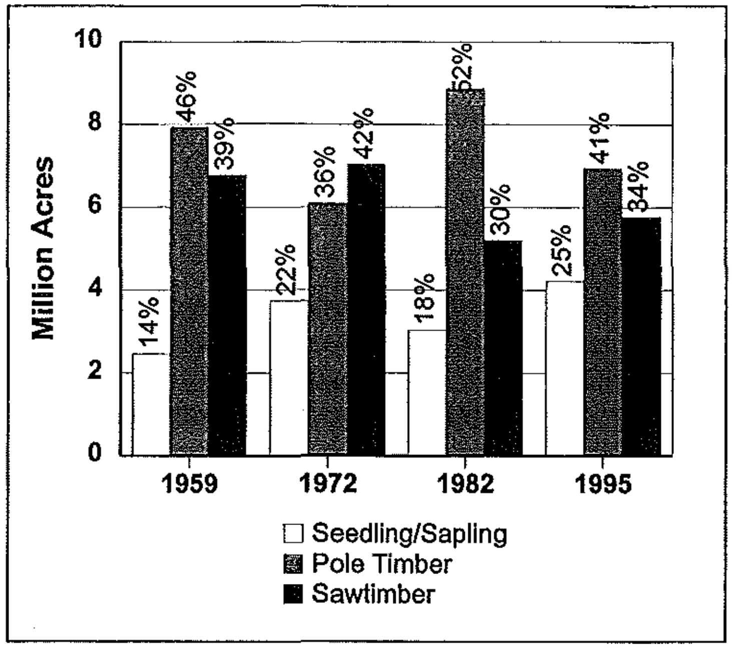



**Figure 2. Changes in Maine's forest. Acres of timberland by stand-size class.**

Figure 3 describes the volume of major species or groups of species for the four inventories of Maine's forest. Species volume changed in response to harvesting practices, insect outbreaks, and the age of stands. Spruce and fir volume peaked in 1971, and is currently at its lowest point since 1971. Hardwood volume has increased, as have other softwood species.

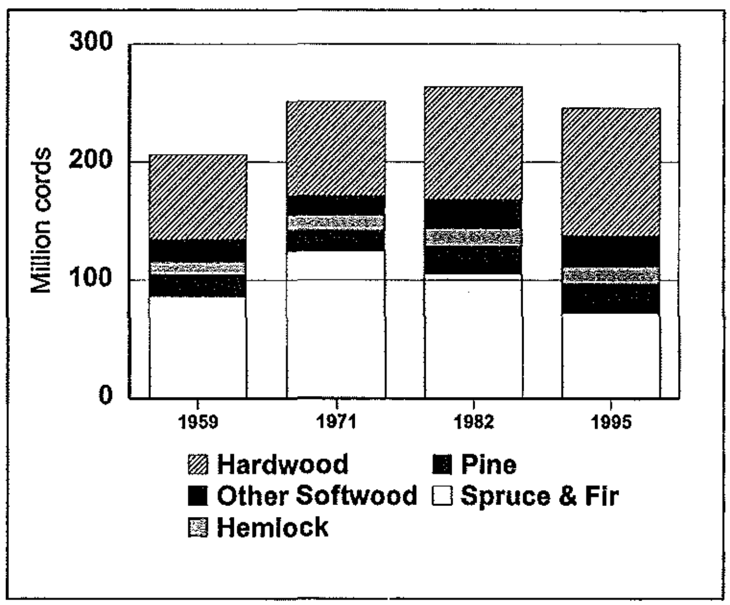



**Figure 3. Growing stock volume of selected species in Maine, 1959 to 1995.**

## C. FOREST COVER TYPES

The 1995 USDA Forest Service inventory of Maine identifies seven major forest cover type groups based on the stocking level of predominant species on a plot.

While the USDA Forest Service has improved its forest typing routines during each of Maine's four forest inventories, comparing acreage by forest type among inventories is problematic. The 1995 inventory reports a substantial decline in the spruce and fir forest type and an increase in the hardwood types (Table 1). Some of this fluctuation is due to revisions in the forest typing routines, while some is due to actual changes in forest composition. It is likely that changes in forest composition occurred on spruce and fir sites that were harvested and are now stocked with other species.

**Table 1. Forest Types in Maine as estimated in four forest inventories. (thousand acres)**

| | 1959 | 1972 | 1982 | 1995 |
|---|---|---|---|---|
| Spruce and Fir | 8,383 | 7,949 | 7,771 | 6,011 |
| Northern Hardwoods | 5,112 | 3,561 | 5,000 | 6,409 |
| Aspen/Birch | 1,243 | 1,419 | 1,505 | 2,250 |
| White/Red Pine | 1,639 | 1,812 | 2,195 | 1,246 |
| Oak/Hickory | NA | 253 | 307 | 456 |
| Elm/Ash/Red Maple | 505 | 1,714 | 238 | 435 |
| Oak/White Pine | NA | 185 | 36 | 128 |
| Pitch Pine | NA | NA | 8 | 7 |
| TOTAL | 16,882 | 16,893 | 17,060 | 16,939 |

While seedling and sapling size trees are considered in assigning forest type, those that are overtopped or occupy lower canopy positions are weighted less in the stocking calculations. The USDA Forest Service definition of forest type emphasizes the species of trees that are merchantable size. Though this may adequately represent short term species trends, it confounds projections of long-term timber supply. For example, when assigning forest type to stands with a low volume of merchantable trees the seedlings and saplings may be under represented with respect to the future development of these stands.

An important part of this timber supply analysis was assigning acres to forest types that best represent the tree species that will occupy sites in the future. A more thorough discussion of forest type allocation is found in the discussion of Base Run specifications, Section III.C. 6. - Forest Type Allocations and in Appendix C.

## D. FOREST GROWTH

The forests of Maine have a proven ability to grow trees and produce wood products. Maine's forest soils, climate and prolific seeding by native tree species combine to produce an abundance of natural regeneration rarely found in other forested regions of the world, but this fortuitous natural condition may not guarantee a stable future timber supply. Forest

growth is strongly influenced by the age-class structure of the forest, mortality from competition and other natural events, and forest practices.

Tree mortality is a direct drain on forest growth and is a significant component of forest development. Young stands in Maine are typically stocked with tens of thousands of trees per acre. As these dense, young stands develop, competition for light, water, and growing space result in significant mortality over the life of the stand. Climatic events such as wind storms and drought can also cause significant mortality in localized areas. Finally, insect and disease outbreaks can periodically cause substantial mortality. Spruce budworm has been the largest source of insect-related mortality in Maine.

Table 2 summarizes the magnitude of statewide mortality for each the four forest inventories in Maine. In the 1982 and 1995 inventories, spruce budworm was the largest single source of mortality.

**Table 2. Estimates of annual mortality in Maine's forests.**

| | 1959 | 1959 - 1972 | 1972 - 1982 | 1982 - 1995 |
|---|---|---|---|---|
| Average annual statewide mortality, all species (million cubic feet) | 272 | 136 | 198 | 226 |
| Average annual statewide mortality, spruce and fir only (million cubic feet) | not reported by species | 75 | 129 | 144 |
| Average annual mortality (cubic feet per acre per year) | 16.1 | 8.1 | 11.6 | 13.4 |

The variation in mortality over the 36 year period is principally explained by the changes in age-class structure and the spruce budworm infestation. A conservative estimate of ongoing or "normal" mortality is that 27% of the merchantable growth occurring in Maine's managed forest eventually ends up decaying on the forest floor. The greatest opportunity to increase merchantable growth in the forest is to use harvesting practices and silvicultural activities that enhance annual growth of trees that can be harvested and utilized. Forest management techniques that increase net growth and yield do so by capturing a portion of the "normal" mortality.

Net Annual Growth, defined as total annual growth minus annual mortality, has declined since the 1972 forest inventory (Figure 4).

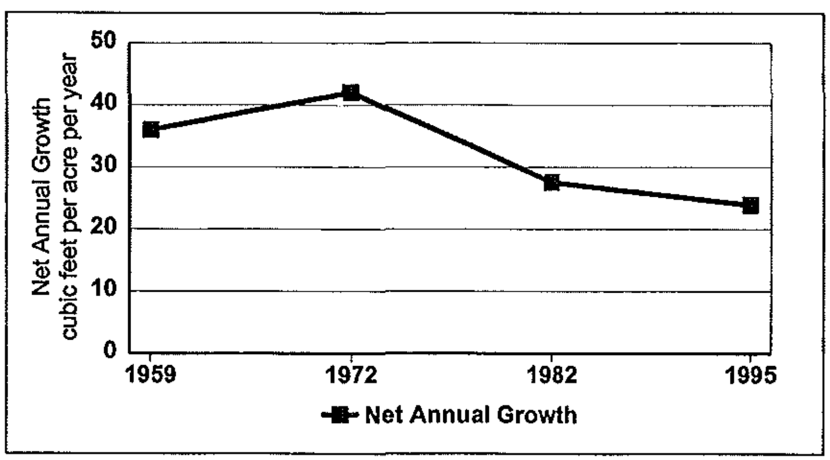



**Figure 4. Statewide net annual growth per acre from Maine's four forest inventories.**

The broad range of growth rates possible under different management regimes in comparison to the historic statewide growth rates are described in Figure 5. Growth is strongly influenced by individual site conditions; therefore management activities with the highest yield are generally applied on sites with the highest growth potential and not to all forest acres.

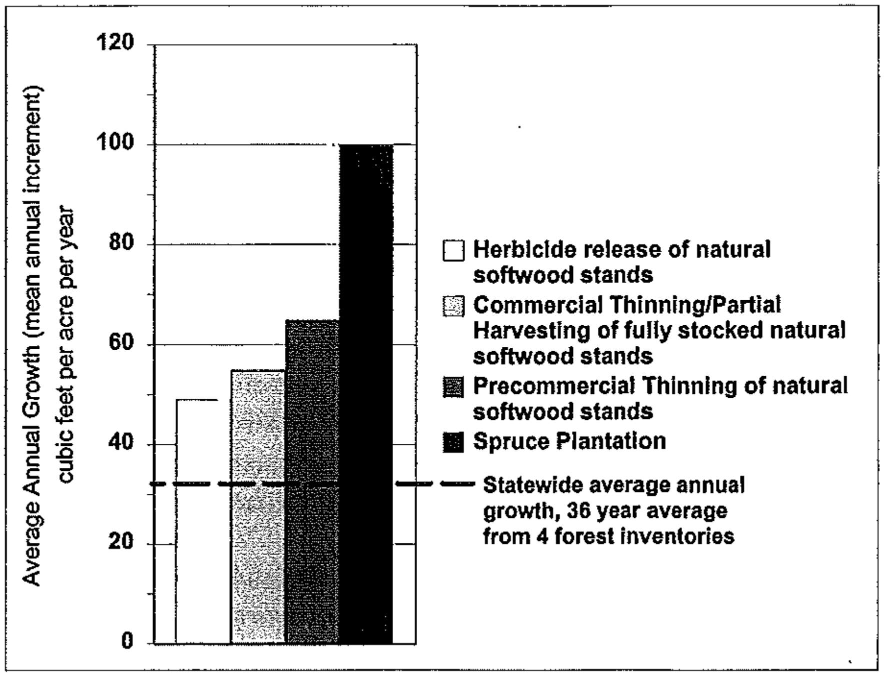



**Figure 5. Comparison of average annual growth rates for different forest management practices in Maine and the statewide 36 year average annual growth** (Seymour 1992 and 1994, Solomon and Frank 1983, and unpublished landowner data).

## E. TIMBER HARVESTING

Over the last 14 years, timber harvesting has occurred on approximately 42% of Maine's forest land (Griffith and Alerich 1996). This pace of harvest clearly makes timber harvesting and the way it is conducted the most important influence on long-term wood supply. Although overall harvest levels have remained somewhat stable, there has been some shifting among species groups as markets and manufacturing technologies change (Figure 6).

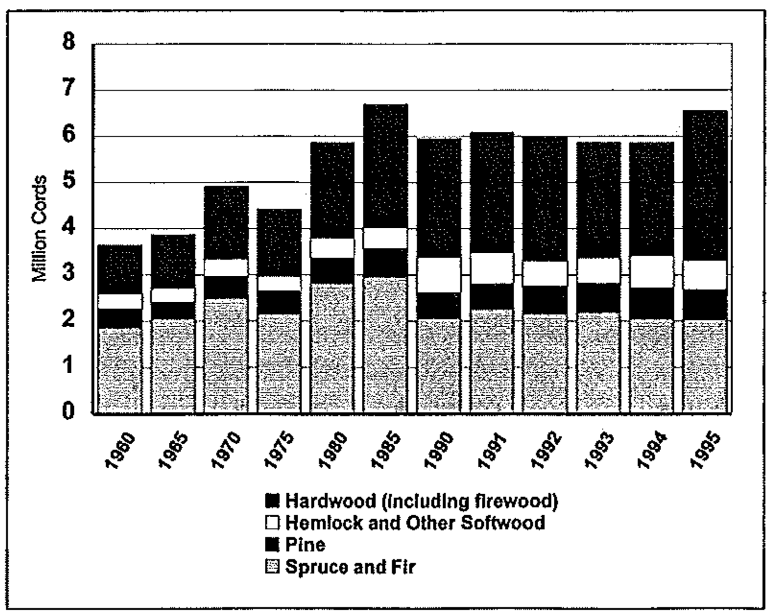



**Figure 6. Harvest of commercially important species in Maine, 1960 t0 1995, all products combined. (Source: Maine Forest Service data.)**

Demand for wood products in Maine grew between 1960 and the mid-1980's. A number of trends shaped Maine's wood-based industries during this period. The mill rebuilds of the 1970's were stimulated by the obsolescence of existing mills, by environmental requirements, and by a growing demand for printing and writing papers. The rebuildings of the 1980's were primarily due to continued demand growth, combined with a significant increase in the price of pulp (Irland 1996). Maine sawmills updated equipment to utilize smaller individual logs and to improve recovery from each sawlog. Another notable trend is the reduction in spruce and fir harvest from the peak in 1985, and the concurrent increase in hardwood harvest.

A wide variety of timber harvesting practices are applied across the diverse conditions of Maine's forest. There are many ways to classify these harvests. For the purposes of this timber supply analysis, we organized harvests at the inventory plot level into 3 volume removal intensity classes: Light (less than 50% volume removal), Moderate (50-80% volume removal) and Regeneration Harvest (80-100% volume removal) (Table 3). While this scheme does not address the more subtle issues regarding quality, diameter, and spacing of residual trees, it does provide a framework and sense of proportion for distinguishing light and moderate partial harvests from regeneration harvests.

**Table 3. Removal Intensity Classes for harvested acres, by forest type group. Forest type groups are as reported in "Forest Statistics for Maine, 1995".**

| | Removal Intensity (acres) | | | Total Harvested Acres |
|---|---|---|---|---|
| Forest Type Group | Light | Moderate | Regeneration Harvest | '1982 to 1995 |
| Spruce/fir | 984,719 | 513,178 | 683,897 | 2,181,794 |
| Northern hardwoods | 1,358,834 | 732,154 | 915,689 | 3,006,677 |
| Aspen/birch | 251,734 | 260,039 | 517,178 | 1,028,951 |
| White/red pine | 352,682 | 175,310 | 40,906 | 568,898 |
| Oak/hickory | 107,784 | 32,911 | 32,429 | 173,124 |
| Elm/ash/red maple | 41,503 | 27,611 | 26,312 | 95,426 |
| Oak/pine | 12,943 | 30,428 | 0 | 43,371 |
| Pitch Pine | 0 | 0 | 0 | 0 |
| Total all Forest Type Groups | 3,110,199 | 1,771,631 | 2,216,411 | 7,098,241 |
| Percent by Removal Intensity Class | 44% | 25% | 31% | |

# *III. TIMBER SUPPLY PROJECTIONS - Base Run*

## A. BACKGROUND

Since Maine's current forest inventory data documents a single point in time, how can this data accurately tell us where we are headed?

Simply extrapolating recent trends into the future can dramatically misinterpret the biological and human influences that shape the forest. Previous extrapolations have not accurately predicted future forest conditions. The USDA Forest Service extrapolated trends to project timber supply as part of the 1972 inventory report. The period between 1959 and 1972 was marked by moderate harvest levels, no major insect or disease problems, and substantial growth. Average annual net growth for the period was 711 million cubic feet per year (approximately 8.4 million cords annually ) while average annual timber removals were 409 million cubic feet (approximately 4.9 million cords annually) (Ferguson and Kingsley 1972). Inventory grew from 188 million cords to 260 million cords.

The 1972 inventory report extrapolated a 20% increase in inventory by the year 2000. In reality, total inventory in 1995 was 3% less than in 1972. The report also forecast a harvest level of approximately 12 million cords annually by 2000. The current annual harvest level is about 6.5 million cords.

How could such a logical extension of data so poorly predict the future? As we now know, 1972 was the calm before a major spruce budworm outbreak. Harvest amounts and species utilization changed substantially, resulting in subsequent decades very different from the 1950's and 1960's. Just as the remeasurement period from 1959 to 1972 did not provide a simple basis for long-term projections, the remeasurement period from 1982 to 1995 also had anomalies that make simple extrapolation inappropriate. This analysis uses growth and yield models and timber supply models to simulate the natural dynamics that determine timber supply.

## B. USING MODELS TO SIMULATE TIMBER SUPPLY

The purpose of this modeling effort was to use the best information about Maine's forests to explore the long-term trends in timber supply. This analysis used the Aggregated Timberland Assessment System (ATLAS) timber projection model, which is primarily an accounting framework that tracks data inputs such as land use changes, shifts in forest cover types, growth and yield projections, timber management, and harvest flows (Mills and Kincaid 1992). The ATLAS model grows and harvests the forest through time to simulate changes in the forest resource. The growth and yield projections required by ATLAS were developed from USDA forest inventory data with the growth and yield model FIBER (Solomon, Herman, and Leak 1995).

The inventory data, growth and yield projections, and the ATLAS model each have an element of error and uncertainty. The simulation of forest dynamics becomes less certain over

longer projection periods. These data and analytical tools are used to make the best assessment possible, but it is crucial that new data and subsequent analysis continue to refine this modeling effort.

Appendix B provides a detailed description of the modeling tools used in this analysis.

## C. BASE RUN - SPECIFICATIONS AND ASSUMPTIONS

The purpose of the Base Run was to simulate the long-term impacts of current harvest levels and current forest management practices on timber supply. As documented earlier, Maine's forest inventory has fluctuated significantly over several decades (Fiqure 1). The Base Run is constructed to examine sustainable wood supply beyond the short-term influence of these fluctuations in inventory.

A discussion of how recent trends and current data were used to build a set of assumptions for the Base Run analysis follows.

### 1. Acreage Available for Harvest

As described earlier, the 1995 forest inventory estimates that 16.9 million acres are available for timber utilization. The timber projection model must accurately account for timberland acreage where timber harvesting is restricted.

Deer Wintering Areas (DWAs), under the jurisdiction of Maine's Land Use Regulation Commission (LURC), are one component of limited-harvest acres. The Base Run identifies 255,000 acres as DWA's and harvests them consistent with regulatory limitations and other management agreements. A portion of these 255,000 acres are not zoned as DWA's, but are managed under special agreements between the Department of Inland Fisheries and Wildlife and several large landowners.

Other areas with limitations on timber harvesting include 1) shore land protection areas of lakes, ponds, streams, and brooks; 2) high elevation protection areas; and 3) lands under harvest easement restrictions. Since the amount of forest land in these designations is not fully defined in any public data base, the analysis did not specifically model these areas. The Base Run assumes that the harvest limitations on these areas are accommodated in the light partial harvest management units.

A third category of forest land where timber harvest might be limited is land held by small, non industrial landowners who own less than 50 acres. A survey of these landowners (Birch 1994) indicates that a significant percentage (34% of all private landowners, owning 5% of all private forest lands in New England) have no intention of ever harvesting timber. However, many of these acres are owned by individuals older than 50 years of age, indicating a possible turnover in ownership within the 50 year time frame of the timber supply forecast. The Base Run does not reduce timberland acres available for harvest to account for this class of landowner.

## 2. Demand for Forest Products

Maine's forest products industries participate in national and worldwide market places. The most recent report on national timber supply and demand projects increases of about 8% and 5% per decade for pulpwood and saw log consumption in the northeast through the year 2040 (Haynes, Adams and Mills 1993). While manufacturing and utilization technologies may change in unpredictable ways, overall demand for forest products is growing as world population grows. At the same time, areas that have traditionally been strong suppliers, such as public lands in the western United States and Canada, are experiencing changes in policy that limit their ability to meet this demand.

The scope of this wood supply analysis does not include testing various demand possibilities for forest products, but rather examines our ability to support current harvest levels. The national timber supply assessment (Haynes, Adams and Mills 1995) supports a timber supply model based on continued strong demand for Maine forest products. In addition, this analysis assumes that the cost of growing, harvesting, and processing Maine forest products will remain competitive for the next 50 years.

## 3. Projected Annual Harvest

The annual harvest level for the Base Run is 559.5 million cubic feet/year (6.582 million cords per year). This harvest level is based on the volume of all pulpwood, firewood, and sawlogs harvested in Maine in 1996. Biomass consumption, 519,000 cords in 1996, is not included in the Base Run harvest level because the majority of biomass is derived from residues of harvested trees (tops and branches) and is not a direct drain on merchantable inventory. The model's growth and yield functions are for the volume of trees 5" diameter or larger, to a 4" top. Biomass volume from branches and tops is not included in the growth and yield functions.

## 4. Species Profile of Projected Annual Harvest

The profile of species harvested has generally followed trends in species inventory. While spruce and fir inventory was building during the 1950's to 1970's, harvest of spruce and fir increased. As spruce and fir inventory declined and hardwood inventory grew during the 1980's and 1990's, spruce and fir harvest declined and hardwood harvest increased. Many Maine pulp mills substituted hemlock and hardwood for spruce and fir (Figure 7).

The Base Run distributes the total harvest volume of 559.5 million cubic feet among all species groups (except cedar) in proportion to the volume of each species group at the end of each decade of the projection. This allocation of harvest recognizes that the market will increase harvesting of species that have increased in inventory and decrease harvesting of species that have decreased in inventory. Northern white cedar is treated differently in the harvest allocation because it is not easily substituted for other species in the manufacturing process.

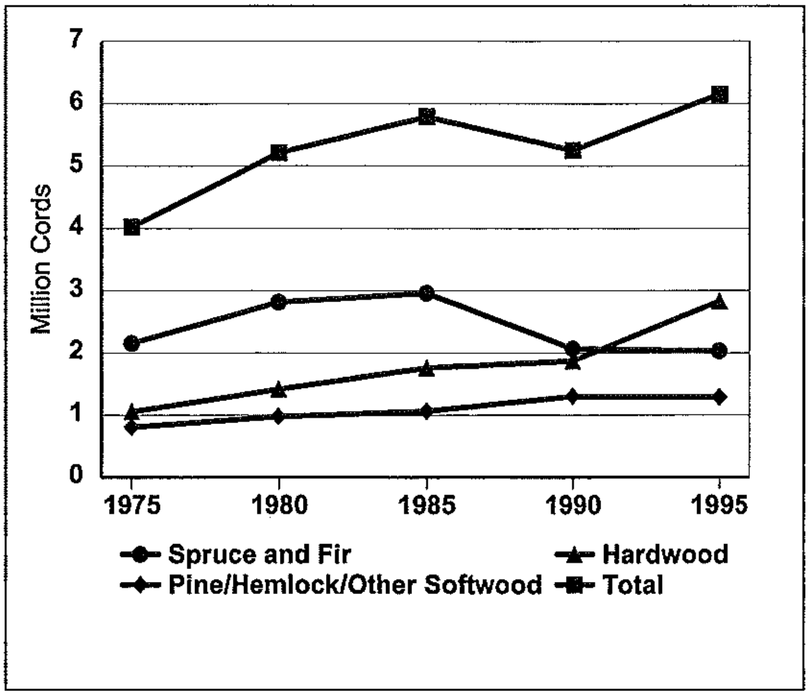



**Figure 7. Harvest of commercially important species in Maine, 1975 - 1995, sawlogs and pulpwood combined.**

5. <u>**Harvest Practices**</u>

The harvest activities documented in the 1995 inventory plots were closely evaluated to build a profile of volume removal intensities for the Base Run simulation. The three harvest intensities are Light partial harvest, Moderate partial harvest and Regeneration harvest. The Base Run is calibrated to conduct harvests that are proportional to the harvest activity documented in the 1995 inventory.

6. <u>**Forest Type Allocations**</u>

The type of timber stand that will grow on a particular forest site is heavily influenced by soil type, elevation, and other geographic features that do not change over time. An understanding of how site characteristics and tree species interact is critical to long-term forecasting. This requires examining the species composition of older trees in the overstory and the species composition of younger seedlings and saplings in the understory that will comprise the future forest. To use the modeling tools to build growth and yield expectations for this analysis, each of the forest inventory plots was assigned to the most appropriate forest type for growth and yield modeling based on evaluation of over-story tree species,

seedling/sapling tree species, soil types, and, for remeasured plots, previous forest type assignment. A detailed discussion of the allocation of inventory plots to forest types in the growth and yield model is presented in Appendix C.

## 7. High-Yield Silvicultural Practices

Some land owners in Maine use high-yield silvicultural practices in young stands, producing no commercial yield but improving future growth and yield. The practices include precommercial thinning of young softwood stands, plantation establishment, and control of competing vegetation in young softwood stands by herbicide applications.

Data relating how these activities enhance tree growth are available from Maine and neighboring forest regions. These activities have been conducted over the past 20 years on a limited number of acres in Maine. In 1995 there were approximately 642,500 acres in high-yield silvicultural practices, about 4% of Maine's timberland acres. The Base Run increases the number of acres treated with high-yield practices at an annual rate equal to the average of 1995, 1996, and 1997 activities, up to the year 2005. In the Base Run the acreage of high-yield silvicultural practices increases to a total of 1.063 million acres by 2005 (6% of timberland acres), and is constant at that number for the duration of the projection (Table 4).

**Table 4. Cumulative acreage of high-yield silvicultural practices included in Base Run.**

| | Acres 1995 | Acres 2005 |
|---|---|---|
| Precommercial Thinning | 137,500 | 324,000 |
| Plantation | 158,000 | 254,000 |
| Herbicide Release [a] | 347,000 | 485,000 |
| Total | 642,500 | 1,063,000 |

a. Herbicide release is adjusted for overlap where thinning or planting sites also receive herbicide application.

## 8. Periodic Natural Events

Several natural events have influenced forest growth in Maine on a significant scale over the years. These events will occur again. In order of magnitude, these events are insect infestation (spruce budworm, hemlock looper, spruce bark beetle), major weather events (wind throw, ice and snow damage), and forest fires.

**Insect Infestation:** The most significant natural event to impact forest growth and health this century is the spruce budworm. Maine's spruce and fir forest will always be at risk from a spruce budworm infestation; however, the magnitude of damage to forest growth and timber loss that results from infestations varies. During the most recent outbreak of the

1970's and early 1980's, the combination of a long-term infestation and the presence of a large amount of mature balsam fir trees resulted in significant mortality and growth loss. It is reasonable to anticipate another spruce budworm infestation during the next 50 years. Two important questions are 1) what age class structure will the spruce and fir forest have when it hosts the next budworm infestation, and 2) what actions will land owners take to limit the impact? The Base Run does not include impacts from another budworm outbreak. A separate sensitivity analysis illustrates possible effects of a spruce budworm outbreak on timber supply (see Section VI. A.).

**Weather Events:** Wind throw damage, often in association with heavy snow, is common in Maine. Historically these events have been most common at a scale of hundreds not thousands of acres. The winter of 1997-98 was an exception. The ice storm of January 1998 caused moderate to extensive damage (50% or more trees in a stand with substantial crown damage) on approximately 2 million acres. As this report was being prepared, the information needed to assess the growth and mortality losses from the ice storm was not fully available. We anticipate the most significant effects of the ice storm will be a reduction in timber quality in the affected areas, rather than reductions in overall growth rates. The Base Run does not include any anticipated losses from weather events.

**Fire:** Prevention and suppression of forest fires has been Maine's most successful forest protection effort. Records back to 1903 indicate that fires frequently consumed 50,000 acres of forest per year, occasionally exceeded 100,000 acres per year, and burned 213,000 acres during the landmark year of 1947. Fire loss since the 1960's has been less than 5,000 acres per year and more typically about 1,000 acres, an insignificant amount to include in a statewide analysis. The Base Run does not include any anticipated losses from forest fires.

## D. RESULTS - BASE RUN

The Base Run is a 100 year projection. The project analysts recognize that modeling natural systems is inherently speculative and simulation results become less precise over longer periods. In interpreting results, conclusions are based on the first fifty years of the simulation, but longer term trends are also used to support the conclusions.

The output of the modeling analysis was evaluated by examining the balance between net growth and harvest over the 50 year projection. Because of the forest's age-class imbalance (an unequal distribution of acreage in old, young, and middle-aged forests), periods where net growth falls below the long-term sustainable harvest level were expected. For purposes of this report, sustainability of timber supply is defined as a long-term (50 year) balance between growth and harvest which results in a stable inventory. The key measure in assessing this balance is the trend in the growth to harvest ratio (Table 5).

**Table 5. Statewide ratio of net growth to harvest at the beginning of each decade, Base Run.**

| | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Statewide ratio of net growth to harvest | 0.80 | 0.80 | 0.86 | 0.92 | 0.94 | 0.88 | 0.82 | 0.83 | 0.85 | 0.87 |

The Base Run analysis indicates that while inventory levels remain adequate to support current harvest levels for the entire forecast period, the continued imbalance between growth and harvest (Figure 8) can not be considered sustainable.

While there is no precipitous drop in available inventory, the current mix of forest management techniques is inadequate to create a balance between harvest and growth over the next fifty years, and inventory steadily declines (Figure 9).

Although the precision of this projection diminishes over time, the projection identifies that net growth under current management is approximately 86% of harvest volume over the 50 year projection period.

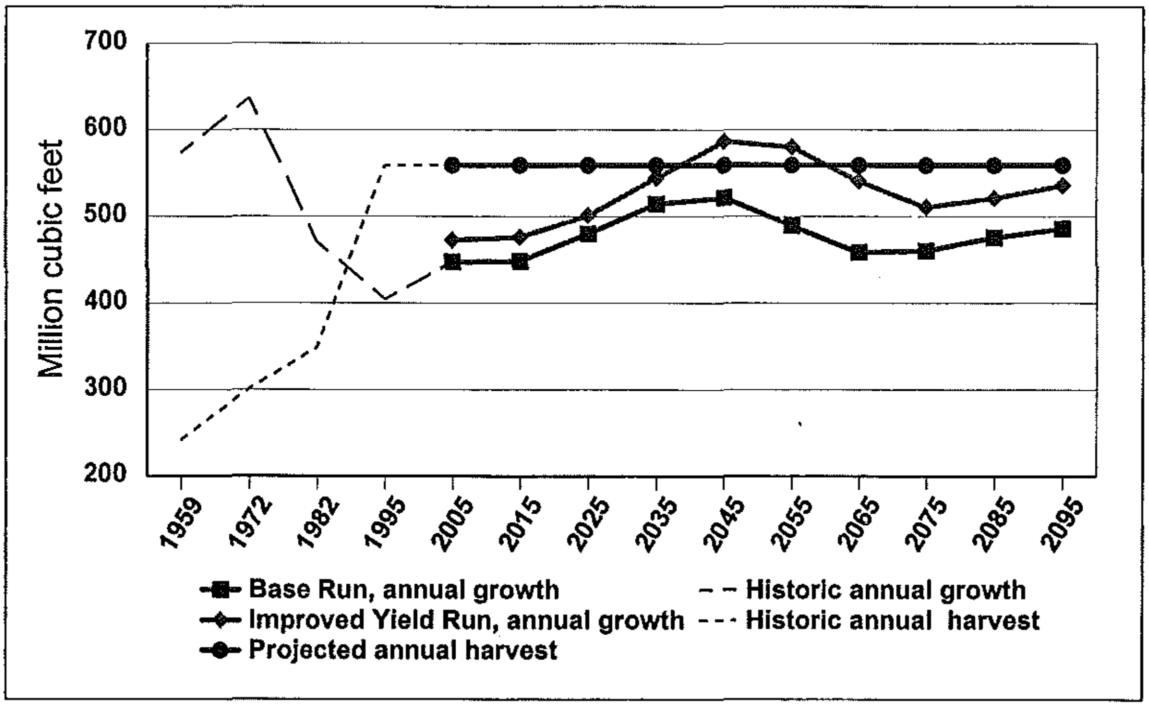



**Figure 8. Projected net annual growth and annual harvest for Base Run and Improved Yield Run. (Data for 1959 to 1995 are from forest inventory reports. Data points after 1995 are based on ATLAS modeling projection.)**

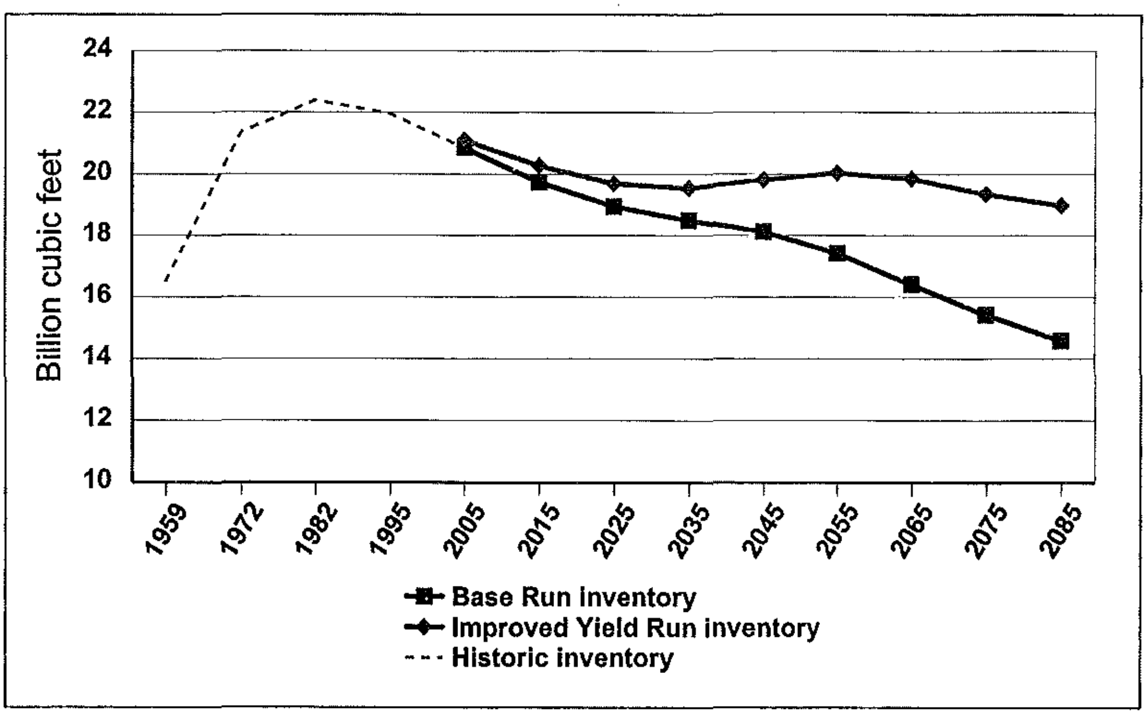



**Figure 9. Projection of statewide inventory for Base Run and Improved Yield Run. (Data for 1959 to 1995 are from forest inventory reports. Data points after 1995 are based on ATLAS modeling projection.)**

## E. SUMMARY FOR MAJOR SPECIES GROUPS

Other observations derived from the Base Run analysis include the following:

1. Spruce and Fir: A significant proportion (25%) of Maine's spruce and fir forest is currently in the seedling or sapling stage. As a result there is a low inventory of merchantable trees. This structure of the spruce and fir forest will result in substantial merchantable growth in the decades from 2010 to 2040. The spruce and fir resource in the Base Run forecast produces an estimated long-term sustainable spruce and fir harvest, under current management, of 180 million cubic feet per year (2.1 million cords per year). The harvest level of spruce and fir in recent years has been 187 million cubic feet per year.

2. Hardwood: Hardwood species account for the largest proportion of Maine's forest inventory. However, net growth is less than projected harvest levels, and inventory is projected to decline for the duration of the 50 year projection. For many decades, much of the hardwood acreage has been over stocked with older, poorly managed stands where only the best quality trees were harvested. More recently, with a stronger pulpwood market for low quality hardwood trees, these stands have been replaced with younger, faster growing trees. However, without improvement in silvicultural practices, existing data does not indicate a sufficient increase in growth to restore balance between growth and current harvest for the hardwood resource. The hardwood resource in the Base Run forecast produces an estimated long-term sustainable hardwood harvest, under current management, of 196 million cubic feet per year (2.3 million cords per year). The harvest level of hardwood in recent years has been 225 million cubic feet per year.

3. White Pine: The future of white pine is difficult to forecast because it exists in small quantities across all forest types in Maine. Consequently, it is not possible to estimate a sustainable harvest for white pine by isolating it in the base run forecast with an acceptable level of statistical certainty. Harvest levels for white pine between 1982 and 1995 averaged about 51 million cubic feet per year. The white pine inventory has been relatively stable in past years, suggesting that currently white pine harvest and growth are roughly in balance. The white pine resource should be better documented and closely monitored.

4. Hemlock: Hemlock has been subjected to increased demand within the last 15 years for all products, but especially as a replacement for spruce and fir pulpwood. It is not possible to estimate a sustainable harvest for hemlock by isolating it in the Base Run forecast with an acceptable level of statistical certainty. From 1982 to 1995, hemlock harvest levels have risen from 25 million cubic feet to 51 million cubic feet annually. The inventory of hemlock declined by a small margin (3%) from 1982 to 1995. The hemlock resource should also be better documented and closely monitored.

# *IV. TIMBER SUPPLY PROJECTIONS - IMPROVED YIELD RUN*

As discussed earlier, better management practices can substantially improve growth and yield in Maine's forest (see Figure 5). These practices include: 1) partial harvesting techniques (such as commercial thinning) that leave well stocked stands of vigorously growing trees, and 2) regeneration harvests that replace poor quality or slower growing stands with vigorous young stands that are cultured to optimize growth. These practices are already occurring in Maine's forest. This section of the report examines how long-term growth might be improved by increasing the area managed with these growth enhancing practices.

The Base Run was modified to identify a profile of managed acres that would establish a long-term balance between growth and projected harvest levels. Modifications to the Base Run include increasing the acreage managed with partial harvesting that promotes the best growth and increasing the acreage of young forest being managed with high-yield silvicultural practices to optimize stand growth. These two criteria were increased in the Improved Yield Run at rates that are attainable in practical terms, and in proportion to the history of their use.

Numerous alternative scenarios could be proposed to simulate improved management practices. The goal of this section is not to examine all the possible combinations of management techniques, but simply to identify the magnitude of change that would achieve sustainable growth rates.

## A. IMPROVED YIELD RUN - SPECIFICATIONS AND ASSUMPTIONS

The Improved Yield Run includes the same assumptions as the Base Run with the following changes:

1. IMPROVED PARTIAL HARVESTING. Sixty-nine percent of harvest activity was classified as some form of partial harvesting (Table 3). These partially harvested acres represent a significant opportunity to increase statewide annual growth with modifications that retain more high quality, vigorous trees at an optimal stocking level. A growth and yield analysis of the inventory plot data indicates that light to moderate harvest removals that leave residual stands of 11 to 20 cords per acre of vigorously growing trees offer the best opportunity for improved growth rates.

The Improved Yield Run moves 4.6 million acres from management units with lower yields over the 100 year projection to partial harvest management units that maintain stands with higher growth rates. This modification represents shifting 25% of Maine's partial harvesting activity into partial harvesting practices that increase net growth.

2 . INCREASED ACRES IN HIGH-YIELD SILVICULTURAL PRACTICES. Substantial increases in net growth per acre can be achieved by more aggressive management activities, such as plantation establishment, precommercial thinning in softwood stands, and competition control with herbicides in softwood stands. These high-yield silvicultural practices,

which require an investment cost, have been implemented on a modest number of acres since their introduction to Maine 25 years ago. By 1995 there were approximately 642,500 acres (4% of Maine's forest land) in high-yield silvicultural practices.

The Base Run increased high-yield silvicultural practices from 4% to 6% of timberland acres by 2005. For the Improved Yield Run, high-yield silvicultural practices increase to 9% (1,560,000 acres) of Maine's timberland by 2015 (Table 6).

**Table 6. Cumulative acres of high-yield silvicultural practices included in Improved Yield Run.**

| | Acres 1995 | Acres 2015 |
|---|---|---|
| Precommercial Thinning | 137,500 | 551,000 |
| Plantation | 158,000 | 316,000 |
| Herbicide Release [a] | 347,000 | 693,000 |
| Total | 642,500 | 1,560,000 |

a. Herbicide release is adjusted for overlap where thinning or planting sites also receive herbicide application.

## B. RESULTS - IMPROVED YIELD RUN

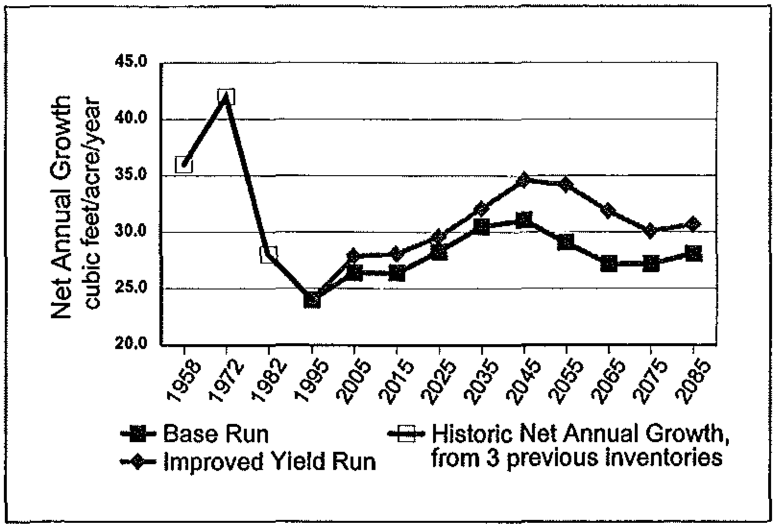
The Improved Yield Run is one practical scenario, based on improved silvicultural practices, that achieves an approximate balance between growth and harvest in the next 50 years (Table 7, Figure 8). Inventory cycles around 20 billion cubic feet (Figure 9).

**Table 7. Statewide ratio of net growth to harvest at the beginning of each decade, Improved Yield Run specifications.**

| | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Statewide ratio of net growth to harvest | 0.85 | 0.85 | 0.90 | 0.97 | 1.05 | 1.04 | 0.97 | 0.91 | 0.93 | 0.96 |

While the Improved Yield Run does not fully capture the details of improved growth rates for individual landowners or individual management practices, it is a practical way to test broad scale changes in management practices and the resulting improvement in statewide growth (Figure 10). By shifting acres to more productive partial harvesting and high-yield silvicultural practices, the statewide average annual growth (50 year average) increases by 7%.

| | Base Run | Improved Yield |
|---|---|---|
| Average annual growth, 50 year average | 28.45 $ft^3$/ac/yr | 30.5 $ft^3$/ac/yr |




On a statewide basis this increase in annual growth is equivalent to a gain of 35.7 million cubic feet each year on 16.9 million acres of timberland; 59% of this gain in annual growth comes from partial harvesting in the Improved Yield Run, and 41% of the gain comes from high-yield silvicultural practices.

**Figure 10. Comparison of statewide net annual growth for Base Run and Improved Yield Run to historic growth rates.**

In order to realize the improvements in growth and productivity, the management activities outlined in the Improved Yield Run need to be aggressively pursued over the next two decades.

## *V. TIMBER SUPPLY PROJECTIONS - Landowner classification*

The 118th Maine State Legislature directed the Maine Forest Service to include analysis by landowner type in an assessment of timber supply. The forest inventory data includes landowner information - facilitating an examination of timber supply by landowner class.

This analysis aggregates Maine's timberland acres into two landowner classes - Large Landowners (owning 100,000 or more acres of forest land in the state) and Other Landowners (owning less than 100,000 acres of forest land), resulting in 9 million acres in the Large Landowner group and 8 million acres in the Other Landowner group. The Large Landowner group represents 15 individual landowners, including multi-generation family ownerships, pulp and paper manufacturers, and sawmill owners.

Grouping landowners in the two classes described above facilitates aggregating the forest inventory data to build the forest cover types, timber management units, harvest flows, and other components required in the ATLAS projection model. The Large Landowners was the easiest group to identify in the forest inventory plot data. This landowner group also has a consistent record of reporting annual harvest data to the Maine Forest Service, allowing a reliable correlation of harvest data to specific forested acres.

**It is important to note that combining the conditions and activities of many landowners within each group masks their diversity of management approaches and harvest activity by averaging for analysis and reporting purposes.**

To assess sustainability of timber supply by landowner type, timber supply was projected separately for each landowner class. A Base Run model was constructed for each landowner class by assigning the pertinent FIA plot data to the appropriate landowner group. Projected harvest level for the Large Landowner category was an average of the annual harvest volumes reported for 1994, 1995, and 1996 by the Large Landowner group. The allocation of the statewide Base Run harvest of 559.5 million cubic feet per year to each landowner group was Large Landowners, 324.5 million cubic feet per year (58%), and Other Landowners, 235 million cubic feet per year (42%).

Base Runs and Improved Yield Runs were conducted for each landowner class, using the same set of assumptions and structure that was used in the statewide Base Run and statewide Improved Yield Run.

## RESULTS - LAND OWNER ANALYSIS

Under current management, the long-term imbalance between growth and harvest over the 50 year forecast seen in the statewide Base Run analysis exists for both landowner groups, but in greater magnitude for the large landowner ownership class (Table 8).

**Table 8. Ratio of Growth to Harvest for Large Landowners and Other Landowners at the beginning of each decade, under current management, Base Run specifications.**

| | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Large Landowner | 0.70 | 0.72 | 0.82 | 0.93 | 0.94 | 0.84 | 0.76 | 0.78 | 0.84 | 0.90 |
| Other Landowner | 0.93 | 0.92 | 0.92 | 0.91 | 0.92 | 0.91 | 0.90 | 0.90 | 0.90 | 0.90 |

Consistent with the approach used in the statewide analysis, we created an Improved Yield run for both Large Landowners and Other Landowners. The same combination of improved management practices used in the statewide Improved Yield run are allocated to each landowner class based on Maine Forest Service data. Table 9 summarizes the practices used in each Landowner Improved Yield Run.

The Improved Yield Runs for both landowner groups indicate a scenario of improved forest practices that increases net growth to the extent that an approximate balance between harvest and growth is achieved within 50 years (Table 10).

**Table 9. Cumulative acres of high-yield silvicultural practices for Large landowners and Other landowners included in Landowner Improved Yield Run.**

| | 1995 | | | 2015 | | |
|---|---|---|---|---|---|---|
| | Large Landowners | Other Landowners | Subtotal | Large Landowners | Other Landowners | Subtotal |
| Precommercial Thinning | 137,500 | 0 | 137,500 | 551,000 | 0 | 551,000 |
| Plantation | 122,000 | 36,000 | 158,000 | 273,000 | 43,000 | 316,000 |
| Herbicide Release | 347,000 | 0 | 347,000 | 693,000 | 0 | 693,000 |
| Total | 606,500 | 36,000 | 642,500 | 1,517,000 | 43,000 | 1,560,000 |

**Table 10. Ratio of growth to harvest for Large landowners and Other landowners at the beginning of each decade, Landowner Improved Yield Run specifications.**

| | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Large Landowner | 0.73 | 0.74 | 0.82 | 0.95 | 1.06 | 1.02 | 0.92 | 0.84 | 0.88 | 0.94 |
| Other Landowner | 0.99 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 0.97 | 0.97 | 0.97 | 0.97 |

# *VI. SPRUCE BUDWORM SIMULATION AND SENSITIVITY ANALYSIS OF YIELD FUNCTIONS*

## A. SPRUCE BUDWORM SIMULATION

Our simulation of a spruce budworm outbreak assumes a ten year outbreak beginning in 2035. Maine Forest Service entomologists identified the decade from 2035 to 2045 as the most likely decade for the next spruce budworm outbreak. During this period a large portion of the spruce and fir forest will be approaching maturity. We acknowledge that the exact timing, length and magnitude of the next budworm event is uncertain.

The budworm simulation has two primary components. The first is reduced growth rates on 6.6 million acres of spruce and fir forest, approximately 95% of the timberland in this forest type. The second component in this scenario is increased removals of spruce and fir to simulate salvage harvesting. To accommodate this change, 20% of the harvest activity in hardwood was

reallocated to spruce and fir. The result is a 14% increase of spruce and fir harvest over the Base Run, while maintaining the overall total annual harvest of approximately 595 million cubic feet. The reduced growth and increased harvesting represent the combined impacts of a significant spruce budworm outbreak.

Compared to the Base Run projection, the results of the budworm scenario are substantial. In the Base Run, the ten year period from 2035 to 2045 shows growth slightly exceeding harvest in spruce and fir (2,463 million cubic feet vs. 2,436 million cubic feet). As a result, for this period the Base Run inventory builds in spruce and fir and declines in hardwood. In the Budworm simulation, growth in spruce and fir is 34% of harvest (955 million cubic feet vs. 2,777 million cubic feet), resulting in an inventory decline in spruce and fir and an inventory increase in hardwood.

The statewide ratio of net growth to harvest in the Budworm simulation shows are marked decrease following the budworm event in 2045 (Table 11).

**Table 11. Statewide ratio of net growth to harvest at the beginning of each decade for the Base Run with spruce budworm infestation from 2035 to 2045.**

| | 2005 | 2015 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Base Run | 0.80 | 0.80 | 0.86 | 0.92 | 0.94 | 0.88 | 0.82 | 0.83 | 0.85 | 0.87 |
| Base Run with spruce budworm infestation | 0.80 | 0.80 | 0.86 | 0.92 | 0.68 | 0.85 | 0.79 | 0.79 | 0.80 | 0.80 |

## B. SENSITIVITY OF YIELD FUNCTIONS

The yield curves that ATLAS uses to grow forest stands through time were adjusted up and down by 10% to test the overall sensitivity of the model to the individual yield curves. Adjusting the ATLAS yield curves downward by 10% results in growth to harvest ratios that are significantly lower than the Base Run ratios for the projection period. Adjusting the ATLAS yield curves upward by 10% approximates a long-term balance of growth to harvest (Figure 11).

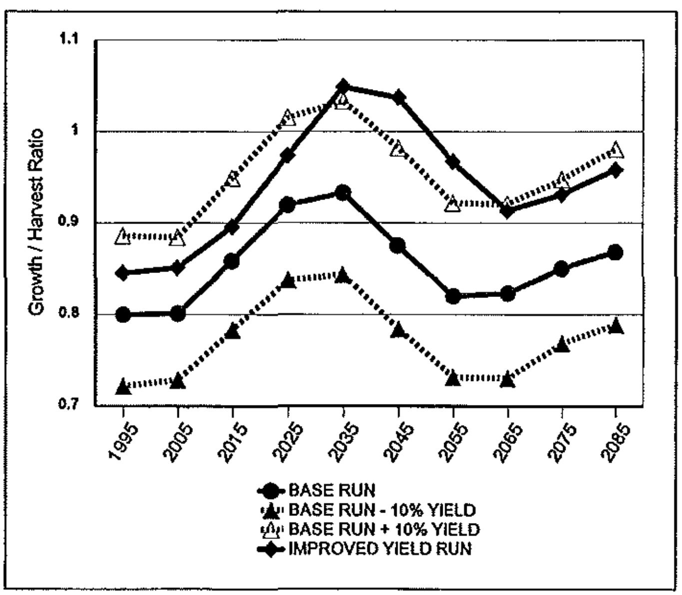



**Figure 11. Comparison of growth to harvest ratios for Base Run, Base Run +/- 10% of yield curves, and Improved Yield Run.**

Making long-term assessments of wood supply requires the best available growth data. The sensitivity of the modeling results to yield curves emphasizes the need for frequent data collection and analysis.

This sensitivity analysis provides another look at the magnitude of long-term imbalance between growth and harvest (Table 12). The trends in growth to harvest ratios for the Improved Yield Run is similar to the trend for the Base Run +10% yield curve.

**Table 12. Growth to harvest ratios for Base Run, Base Run +/- 10% of yield curves, and Improved Yield Run.**

| | 2005 | 2010 | 2025 | 2035 | 2045 | 2055 | 2065 | 2075 | 2085 | 2095 |
|---|---|---|---|---|---|---|---|---|---|---|
| Base Run -10% Yield | 0.72 | 0.73 | 0.78 | 0.84 | 0.84 | 0.78 | 0.73 | 0.73 | 0.77 | 0.79 |
| Base Run | 0.80 | 0.80 | 0.86 | 0.92 | 0.93 | 0.88 | 0.82 | 0.82 | 0.85 | 0.87 |
| Base Run +10% Yield | 0.89 | 0.88 | 0.95 | 1.02 | 1.03 | 0.98 | 0.92 | 0.92 | 0.95 | 0.98 |
| Improved Yield Run | 0.85 | 0.85 | 0.90 | 0.97 | 1.05 | 1.04 | 0.97 | 0.91 | 0.93 | 0.96 |

# *VII. PREVIOUS TIMBER SUPPLY ANALYSES*

Two earlier projects, both funded by the Maine Department of Conservation - Maine Forest Service, evaluated Maine's timber supply outlook. Since the current data are well within their forecast periods, it is useful to review the results of these earlier analyses.

The first analysis, conducted by the J.W. Sewall Co. for the Maine Forest Service in 1983, used the USDA Forest Service survey data from 1982 to model supply of spruce and fir (J.W. Sewall Company 1983). It was the first analysis to use computer modeling to address long-term timber supply in Maine. The report identified the following factors as contributing to an unfavorable forecast for spruce and fir supply: 1) the unbalanced age structure of Maine's spruce and fir forest; 2) mortality from spruce budworm; 3) lack of high-yield intensive silvicultural practices; 4) high harvest levels of spruce and fir; 5) low utilization rates of harvested trees, both at the harvest site and in the manufacturing process.

The Sewall report concluded that:

1. Spruce and fir inventory would decline by 50% from 1982 to 1995 (from 9.2 billion cubic feet to 4.4 billion cubic feet);
2. Spruce and fir harvest levels in 1982 were not sustainable without a major increase in high-yield silvicultural practices. Higher stumpage prices could accelerate implementation of high-yield practices;

3. Alternatively, a harvest level equal to 75% to 90% of the 1982 spruce and fir harvest was sustainable; and
4. Improvement in the utilization of harvested trees, both at the harvest site and in the manufacturing process, could reduce the drain on the resource and to some extent moderate projected supply shortfalls.

What actually happened between 1983 and 1995 was:

1. Spruce and fir inventory declined by 30% (from 9.2 billion cubic feet to 6.3 billion cubic feet);
2. Increases in high-yield silvilcultural practices in spruce and fir occurred at a modest rate;
3. Spruce and fir harvest levels in Maine declined from the 1983 level by 25% (from 245 million cubic feet per year in 1982 to 187 million cubic feet per year in 1990 through 1996);
4. Stumpage prices have significantly improved. Between 1982 and 1990, stumpage prices for spruce and fir pulpwood and sawlogs rose 12% and 28%, respectively; and
5. Utilization of smaller diameter trees has dramatically improved in spruce and fir sawmills.

The 1983 forecast was fairly accurate considering the dramatic changes that have occurred in the spruce and fir forest. Instead of a spruce budworm outbreak continuing until 1992, as projected in 1983, it disappeared around 1985. The 1983 analysis was a significant catalyst in shifting pulp mill utilization from spruce and fir to a more diverse species mix utilizing more hardwood and hemlock. The combination of a shorter than anticipated spruce budworm outbreak and less harvest pressure modified circumstances to the point that the Base Run forecast in this 1998 analysis is consistent with the forecast of the 1983 spruce and fir supply/demand analysis.

Seymour and Lemin conducted an independent timber supply analysis in 1989 that forecast timber supply for all major species groups in Maine (Seymour and Lemin 1989). The spruce and fir resource data was updated from the 1983 report with a mid-cycle survey of the spruce and fir inventory. The report's key points are:

1. The spruce and fir resource was much closer to a balanced growth/harvest ratio than the 1983 report projected, but cannot indefinitely sustain the spruce and fir harvest of the mid to late 1980's.
2. The hardwood resource, while having a substantial inventory, was projected to decline under existing and future harvest pressure. This report was the first to raise concern over the balance of hardwood growth and harvest. The report used a separate demand analysis to predict increased harvesting of hardwood in Maine. This prediction has proven accurate to date. Harvest of hardwood in Maine rose from under 200 million cubic feet in 1990 to 238 million cubic feet in 1996 - a 20% increase.

3. The report identified a need for more intensive silvicultural practices to avert the forecasted shortfall for all species groups. The report concluded that a four- to six-fold increase in area in high-yield silvicultural practices (from 30,000 acres per year to 100-150,000 per year) was necessary to restore full balance between growth and harvest.

# *VIII. FUTURE ANALYSES*

This is the first long range forecast of Maine's timber supply since Seymour and Lemin's 1989 timber supply forecast (Seymour and Lemin 1989). This analysis should provide a sound framework for evaluating public policy and the future direction of forest management in Maine. However, the best way to utilize these computer simulation tools is to constantly refine our assumptions and introduce increasingly better data.

At the direction of the 118th Maine legislature, and in partnership with the USDA Forest Service, the Maine Forest Service will begin an annual forest inventory program in 1999. Approximately 20% of Maine's 3,000 forest inventory plots will be remeasured every year. In addition to providing more timely data, the annual program will allow for modification of inventory procedures to assure that the data necessary to answer our forest policy questions are collected. Tying this data collection to an ongoing forest modeling program will facilitate refinement and improvement in our analytic efforts.

Future analysis should include the following:

1) Forecasting Product Quality Trends.

While Maine's diverse forest industry can utilize trees of various qualities, trees of veneer and sawlog quality are the hardest to grow and the most profitable to harvest. Since the first forest inventory in 1959 there have been concerns about the availability of high quality trees. The forest practices necessary to increase the availability of these products need to be better documented and monitored. Detailed analyses of specific products such as birch veneer, maple sawlogs, and white pine sawlogs will require more precise data about stem quality.

2) Forecasting Tree Species Trends.

Understanding and documenting the development of seedling and sapling-sized forest stands could improve the precision in timber supply modeling. This analysis uses seedling and sapling data from the 1995 forest inventory, but better inventory information on young stands will strengthen future modeling work.

One concern is the trend in red spruce, this species has the highest growing stock volume. Red spruce along with balsam fir experienced a significant decline in merchantable inventory since 1982. Both species show a strong increase in seedling-sized trees; however balsam fir is more aggressive than red spruce in dominating stands over time. Red spruce is poised to regain

its previous role in Maine's forest, but it may need some special attention to assure this outcome. Future data collection and analysis should focus on the development of red spruce.

White pine is another candidate for more refined analysis. White pine's presence in many forest types across the state in low, scattered volumes makes it more difficult to model its dynamics with confidence. The importance of white pine to many Maine sawmills warrants a more specific evaluation than this analysis is able to provide.

3) Acreage Available for Timber Utilization

Future work should include a more complete public data base on forest acres that are subject to harvesting restrictions, or are being held without any harvesting or management activities.

4) Harvest Activity

The new annual forest inventory will provide an important opportunity to better understand the profile of harvesting activities and trends in these activities. This analysis demonstrates the importance of knowing the details of actual harvest activities and the condition of residual forest stands. Harvest activity assessment should be better integrated into the data collection providing more specific data to refine future modeling analysis.

5) Economic Modeling and Forecasts

Future analysis of timber supply should include an integrated analysis of the economic forces that shape demand for various kinds of forest products, as well as documenting the financial basis for investing in improved yield forest practices. Market demand, wood supply, stumpage prices, and costs of improved yield silvicultural practices must be understood and evaluated as a package. As with the biological factors that shape the forest, economic factors are influenced by trends that warrant close monitoring.

# Literature Cited


Birch, Thomas W. 1996. Private forest-land owners of the Northern United States, 1994. USDA For. Serv. NE For. Exp. Sta. Resource Bull. NE 136. 293 p.

Daubenmire, Rexford. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monographs 22:301-330

Ferguson, R. H. and F. R. Longwood. 1960. The timber resources of Maine. USDA For. Serv. NE For. Exp. Sta. (unnumbered), Upper Darby, PA. 75 p.

Ferguson, R. H. and N. P. Kingsley. 1972. The timber resources of Maine. USDA For. Serv. Resource Bull. NE-26. 129 p.

Fajvan, M. A., S. T. Grushecky, and C. C. Hassler,. 1998. The effects of harvesting practices on West Virginia's wood supply. Journal of Forestry 5:33-39.

Griffith, D. M. and Alerich, C. L. 1996. Forest statistics for Maine, 1995. USDA For. Serv. Resource Bull. NE-135. 134 p.

Growth and Yield Model Version 1.0. 1993. Public domain software. Forest Research Section, Nova Scotia Department of Natural Resources.

Haynes, R. W., D. M. Adams, and J. R. Mills. 1995. The 1993 RPA Timber Assessment Update. USDA For. Serv. General Technical Report RM - 259. Fort Collins, CO. Rocky Mountain Forest and Range Experiment Station 66 p.

Irland, Lloyd C. 1996. Land, timber and recreation in Maine's Northwoods: Essays by Lloyd C. Irland. Maine Agricultural and Forest Experiment Station. University of Maine. Misc. Publ. 730. 81 p.

Kettela, E. G. 1983. A cartographic history of spruce budworm defoliation from 1967 to 1981 in Eastern North America. Canadian Forestry Service Information Report DPC-X-14. Maritimes Forest Research Centre, Fredericton, N. B.

Leak, William B. 1982. Habitat Mapping and Interpretation in New England. USDA Forest Service Research Paper NE-496.

Mills, J. R. and J. C. Kincaid. 1992. The Aggregate Timberland Assessment System - ATLAS: A Comprehensive Timber Projection Model For. Serv. Gen. Tech. Report PNW-GTR-281.

Pfister, R.D. and S.F. Arno. 1980. Classifying Forest Habitat Types Based on Potential Climax Vegetation. Forest Science. 26:52-70.

Powell, D. S. and D. R. Dickson. 1984. Forest Statistics for Maine, 1971 and 1982. USDA For. Serv. Resource Bull. NE-81. 194 p.

Sewall Co., J. W. 1983. Spruce-fir wood supply/demand analysis. Final report submitted to: Maine Dept. Conservation, Augusta, ME. 94 p. + appendix.

Seymour, R. S., and R. C. Lemin. 1989. Timber supply projections for Maine, 1980 - 2080. College of Forest Resources, Maine Agricultural Experiment Station, University of Maine, Misc. Report 337. 39 p.

Seymour, R. S., and R. C. Lemin. 1991. Empirical yields of commercial tree species in Maine. College of Forest Resources, Maine Agricultural Experiment Station, University of Maine, Misc. Report 361. 112 p.

Seymour, R. S. 1992. Production silviculture in northeastern North America. In: American Forestry - An evolving tradition. Proc. Society of American Foresters National Convention, Richmond, VA. Oct. 17, 1992. Society of American Foresters, Bethesda, MD. pp. 227-232.

Seymour, R. S. 1993. Options for high-yield silviculture: plantations or natural stands? In: Briggs, R. D. et al. Nurturing the northeastern forest: a conference on stewardship in a changing culture. Proc. New England Society of American Foresters Annual Meeting, Portland, ME. March 3 - 5, 1993.

Seymour, R. S. 1994. The Northeastern Region - Ch.2 in Regional Silviculture of the United States, 3rd ed., Edited by John. W. Barrett. John Wiley & Sons, Inc.

Solomon, D. S. and R. M. Frank. 1983. Growth response of managed uneven-aged northern conifer stands. USDA Forest Service, Res. Pap. NE-517. 17 p.

Solomon, D. S., D. A. Herman and W.B. Leak 1995. FIBER 3.0: An ecological growth model for northeastern forest types. USDA Forest Service, Northeastern Forest Experiment Station. Gen. Tech. Report NE-204.

Solomon, D. S., R. A. Hosmer and H. T. Hayslett, Jr. 1986. A two-stage matrix model for predicting growth of forest stands in the Northeast. Canadian Journal of Forest Research.16:521-528.

Solomon, D. S. and T. B. Brann. 1997. FlexFiber 4.155. Public domain software from USDA Forest Service Northeast Experiment Station. Durham, NH.

Solomon, D. S., T. B. Brann and L. E. Caldwell. 1999. Adaptation of FIBER for Forest Inventory and Analysis growth projections in the state of Maine. Proceedings of the Second International Symposium on Integrated Tools for natural resource inventory in the 21st century at an International Conference on the Inventory and Monitoring of Forested Ecosystems, August 16-20, 1998, Boise, ID -- in press.

Turner, R. J. and P. E. Sendak. 1994. The Atlas model and the RPA resource assessment for the Northeast: Assessing data sources and projection alternatives for uneven-aged forests. USDA For. Serv. Northeastern Forest Experiment Station. (unpublished) 57 p.

Webb, F. E., J. R. Blais, and R. W. Nash. 1961. A cartographic history of spruce budworm outbreaks and aerial forest spraying in the Atlantic region of North America, 1949-1959. The Canadian Entomologist. Vol. XCIII, Number 5.

## APPENDIX A.

### Maine Forest Service
### Timber Supply Outlook for Maine: 1995 - 2045

### Project Co-leaders

Richard Birdsey
USDA Forest Service
Global Change Research Project
Radnor, PA

Charles Gadzik
Maine Forest Service
Augusta, ME

### Project Staff

Robert Turner
RJT Company
Bristol, VT

Lawrence E. Caldwell
Maine Forest Service
Augusta, ME

James Blanck
Maine Forest Service
Augusta, ME

### Technical Review Team

Thomas Brann
College of Natural Sciences, Agriculture and Forestry
University of Maine

John Kolenik
Seven Islands Land Company
Bangor, ME

Dale Solomon
USDA Forest Service
Durham, NH

Rob Bryan
Maine Audubon Society
Falmouth, ME

Kenneth Laustsen
Great Northern/Bowater
Millinocket, ME

Peter Triandafillou
J. M. Huber Resources Group
Old Town, ME

MaryEllen Chilelli
Maine Dept. of Inland Fish and Wildlife
Bangor, ME

Gordon Mott
Forester in private practice
Lakeville, ME

Will McWilliams
USDA Forest Service
Radnor, PA

David Edson
J. W. Sewall Company
Old Town, ME

Paul Sendak
USDA Forest Service
Durham, NH

Jeffrey Gove
USDA Forest Service
Durham, NH

Robert Seymour
College of Natural Sciences, Agriculture and Forestry
University of Maine

## APPENDIX B. Modeling Tool Descriptions

This analysis relied primarily on two computer modeling tools in making projections of timber supply for the next 50 years.

1) The Aggregated Timber Supply System (ATLAS) (Mills and Kincaid 1992) is a tool used by the USDA FOREST SERVICE to predict timber inventories at the national level. The ATLAS model simulates growth, harvest, and regeneration of aggregated timber stands over time. The basic requirements for a simulation are a starting inventory, estimates of growth and yield for different forest stands, and estimates of future harvest. Different options allow for representing changes in timberland area and projecting trends in timber management.

2) FlexFIBER (Solomon and Brann 1997) is a growth/yield model developed for use in the Northeastern United States. The Flex component is an inventory data processor that provides many options desirable in doing aggregate plot projections, such as post projection volume averaging on multiple plot projections. The FIBER 3.0 component (Solomon, Hosman and Hayslett 1986; Solomon, Herman and Leak 1995) is a diameter class, stand table projection model that simulates the growth/yield of individual stands over a large range of management treatments. FIBER uses species, diameter, ecological land classification, elevation, initial basal area, residual basal area, and proportion of hardwoods to predict growth and mortality by diameter class. Management practices and silvicultural treatments can be applied over a range of stand densities, harvest intervals, and species composition for each of the different ecological land classifications.

FIBER 3.0 was used to predict growth and yield for all management units except those being managed under high-yield silviculture (plantation, precommercial thinning, and herbicide release). Yield curves for the high-yield silvicultural practices were developed from normal yield curves, and projected by the Growth and Yield model (GNY) (Nova Scotia Department of Natural Resources 1993). The modifications of the GNY curves were based on both a review of pertinent literature and data solicited from large landowners. These growth and yield estimates were then used to supply the growth and yield parameters required by ATLAS. The ATLAS model provides a complete accounting of inventory, growth, acreage, and harvest by age class and management intensity for each specified period of the modeling time frame. The models were calibrated with data from the 1995 Forest Inventory of Maine (Griffith and Alerich 1996).

## APPENDIX C. Adaptation of FlexFiber for growth projections of forest inventory plots in Maine.

Introduction

In completing the 1995 forest inventory for Maine, the USDA Forest Service measured 2,698 plots describing Maine's roughly 17 million acres of timberland. Responding to a strong public need for information on the sustainability of current harvest levels, the Maine Forest Service initiated a collaborative study utilizing this inventory data in a projection of Maine's future timber supply. A technical review team with diverse backgrounds chose the FIBER model (Solomon, Herman and Leak 1995) to provide a timberland stratification scheme and generate some of the yield inputs for the ATLAS timber projection model (Mills and Kincaid 1992).

The USDA Forest Service defines forest type as "a classification of forest land based on the species that form a plurality of live-tree basal-area stocking" (Griffith and Alerich 1996). The forest types of Maine's woods, and even the algorithms used to define them, have changed rather significantly over the last 4 decades. These changes are due to both natural processes and human disturbance. Conversely, FIBER's ecological habitats are intended to describe the land itself, and are stable over time. These habitats are indicative of the probable climax or late successional overstory species composition that is theoretically determined by a set of biophysical relationships related to site quality (Leak 1982). This typing scheme is similar to binomial habitat that state the predominant overstory/understory of potential climax vegetation, as originated in the western United States (Daubenmire 1952, Pfister and Arno 1980). By using plot level data to stratify all timberland into one of FIBER's six ecological habitats, FlexFIBER and ATLAS were integrated, producing an ecologically based timber supply projection (Solomon, Brann and Caldwell 1999.

Methods and Results

The 1995 FIA (Forest Inventory and Analysis) database "METRE_95" contains 183 variables including past (1982 inventory) and current tree list information as well as seedling/sapling data tallied in the 1995 remeasurement. The lower size limit for these understory trees is 12 inches in height. All 2,698 timberland plots were processed through the FlexFIBER model in two separate runs to generate independent overstory and understory ecological habitat assignments. The understory of a plot is normally overlooked as an input to the FlexFIBER model. In our situation however, we used the FIA understory data to aid in assessing the ecological habitat. This was particularly important for plots in the Spruce/Fir habitat that currently have a fairly high level of red maple (*Acer rubrum*), poplar (*Populus spp.*), paper birch (*betula paperifera*), and northern white cedar (*Thuja occidentalis*) stocking in the overstory.

We used all live trees greater than or equal to 4.5" dbh for the overstory run and all live trees less than 4.5" dbh for the understory run. While the overstory run used FlexFIBER 's traditional statistic generated from the basal area of individual species found on the plot, the model was adapted in the understory run to use a statistic based on number of trees per acre. This adjustment more accurately describes the understory, which could be misrepresented using only basal area of the overstory. This typing algorithm looks at the above statistics from the standpoint of species in the existing vegetation which, through an implied association to different soil characteristics, are indicative of successional trends. This initial assignment by FlexFIBER

led to the following distribution of acres, acknowledging that 135 plots had less than the required 5 square feet of basal area required by the model and therefore were not included in this first distribution.

FIBER 's base run with no changes:

| FlexFIBER OVERSTORY HABITAT | ACRES | % OF ACRES | % HARDWOOD BA |
|---|---|---|---|
| Beech/Red Maple | 2,367,769 | 14.6% | 91% |
| Cedar/Black Spruce | 2,851,104 | 17.6% | 19% |
| Hemlock/Red Spruce | 1,629,054 | 10.0% | 34% |
| Oak/White Pine | 2,248,710 | 13.9% | 47% |
| Spruce/Fir | 5,188,685 | 32.0% | 36% |
| Sugar Maple/Ash | 1,930,294 | 11.9% | 92% |

We divided the plots representing the above distribution into 3 groups based on the conflict between the overstory and understory assigned by the FlexFIBER model. The groups were as follows.

1. Plots with disagreement- There were 1,362 plots that had different understory and overstory habitat assignments.

2. Plots with agreement- There were 1,201 plots that had agreement between the understory and overstory habitat assignments.

3. Plots with no overstory- There were 135 plots that had no overstory and did not fall into the above 2 groups.

All 2,698 timberland plots were profiled using plot variables that describe the FlexFIBER overstory/understory, plot elevation, soils information, current and past forest type as determined in the USDA Forest Service 1982 and 1995 forest inventories. Plots were sorted by FlexFIBER understory and 1982 FIA forest type, within a given FlexFIBER overstory, allowing aggregation of plots with similar attributes. There was agreement between overstory and understory on 1,201 plots; their habitat classification did not change. The data describing these plots indicated few opportunities to improve the habitat assignments in this subset. The plots with disagreement between the overstory/understory and plots with no overstory recorded received further evaluation.

There were 1,497 (1,362 + 135) plots that were considered for overstory reassignment. This was a two phase process. In the first phase, we grouped the "disagreement plots" by FlexFIBER 's suggested overstory habitat class. After also examining tree list data, it became apparent that some general rules could be developed to move groups of plots with similar characteristics into more appropriate FlexFIBER habitat. For example, it seemed that some Sugar Maple/Ash plots on high quality sites (mesic soils with parent material of glacial tills or alluvium, Sugar Maple/Ash understory) failed to meet FlexFIBER's basal area requirements for a Sugar Maple/Ash overstory. Recognizing the persistence of a Sugar Maple/Ash understory on better soils, as well as the homogeneity of many of these plots, we made a general rule to reassign these plots to the Sugar Maple/Ash habitat. The 1982 FIA forest type was of particular importance in the stratification because it documented the species of preharvest stocking for many of the plots harvested over the resurvey period. In total, 14 rules were developed for

changing the FlexFIBER habitat assignments of 539 plots. Most rules changed less than 50 plots. The 3 rules responsible for changing the most plots (57% of the plots changed) are listed below.

1. All plots with a FlexFIBER understory of Sugar Maple/Ash and Sugar Maple/Ash soils were assigned a FlexFIBER habitat of Sugar Maple/Ash (82 plots).

2. All plots with a FlexFIBER overstory of Beech/Red Maple and an understory of Spruce/Fir and an old FIA forest type of either red-white spruce, fir, aspen, or birch were assigned a Spruce/Fir FlexFIBER habitat (79 plots).

3. All plots with a FlexFIBER overstory of Cedar/Black Spruce and an understory of Spruce/Fir and an old FIA forest type of red-white spruce or fir were assigned a Spruce/Fir FlexFIBER habitat (146 plots). (If new plot with unrecorded old FIA type, the current FIA forest type may be substituted for old FIA forest type.)

The first phase also included assigning the 135 plots with no overstory. In this case, the same 12 plot descriptor variables and tree list data were used, but plots were placed individually without any rules being explicitly stated. Because these plots lacked an overstory assignment and were fewer in number, profiles of groups of plots were less meaningful. The FlexFIBER understory assigned in the original run and the past forest type were most meaningful here. The results of the Phase I assignments was a distribution of total timberland acres as listed below.

Distribution after Phase I:

| FlexFIBER OVERSTORY HABITAT | ACRES | % OF ACRES | % HARDWOOD BA |
|---|---|---|---|
| Beech/Red Maple | 2,876,515 | 17.0% | 77% |
| Cedar/Black Spruce | 1,599,084 | 9.4% | 15% |
| Hemlock/Red Spruce | 1,447,076 | 8.5% | 30% |
| Oak/White Pine | 1,928,361 | 11.4% | 43% |
| Spruce/Fir | 6,599,835 | 38.9% | 36% |
| Sugar Maple/Ash | 2,501,361 | 14.8% | 87% |

The second phase of the FlexFIBER overstory assignments was meant to be at a higher level of resolution, with the intent of correcting plots that either could not or should not be captured by broad classifying rules. This process was one of sharing opinions of the changes made to individual plots by the broad and inspecting tree lists of individual plots that were questionable.

The results of the second phase assignments was a distribution of timberland acreage as listed below. It reflects a higher percentage of Spruce/Fir, Sugar Maple/Ash, and Beech/Red Maple acres than the original FlexFIBER base run output, while also reflecting a lower percentage of Cedar/Black Spruce, Hemlock/Red Spruce, and Oak/White Pine acres. This was the distribution used by the ATLAS timber supply analysis.

Distribution after Phase II:

| FLEX FIBER OVERSTORY HABITAT | ACRES | % OF ACRES | % HARDWOOD BA |
|---|---|---|---|
| Beech/Red Maple | 3,187,980 | 18.8% | 73% |
| Cedar/Black Spruce | 1,612,559 | 9.5% | 14% |
| Hemlock/Red Spruce | 1,290,525 | 7.6% | 31% |
| Oak/White Pine | 1,290,311 | 7.6% | 42% |
| Spruce/Fir | 6,909,619 | 40.8% | 35% |
| Sugar Maple/Ash | 2,661,238 | 15.7% | 86% |

As we try to assess the accuracy of our chosen distribution, it is helpful to look at the past. For a variety of reasons, Maine forests during the 1940s, 1950s, and 1960s experienced less harvesting than they have recently. We believe that forest type data from this period better reflects later stage successional trends in Maine than the current FIA forest type. For example, the 1959 FIA inventory (Ferguson and Longwood 1960) recorded 8.4 million acres of spruce-fir type group as compared to the 1995 FIA inventory of 6 million acres. Though the typing algorithms have changed since 1959, it is safe to say that harvest activity over the past three decades on these former spruce-fir sites has promoted a higher stocking level of both hardwoods and northern white cedar while decreasing stocking levels of spruce and fir. However, many of these stands have a strong component of spruce and fir in the understory, in many cases reflecting the successional tendency of these sites. Our approach combines the convenience of FlexFIBER's batch level processing with the valuable understory, soils, and forest type information in the forest inventory.

## Conclusion

With Maine's timberland acres aggregated into these six ecological classes, we constructed yield curves based on a variety of removal intensities and silvicultural regimes. In this process, all timberland plots (except the 135 lacking an overstory) were projected by the FlexFIBER model, which accommodates post projection averaging of plots. These averaged yield curves, stratified by the above ecological habitats as well as by volume classes, provided most of the yield information used as inputs to the ATLAS model. By using an ecological habitat approach as the primary model stratum, the ATLAS formulation allows the consequences of alternative silvicultural regimes to be directly tied to site quality and longer term species trends.

## APPENDIX D. Summary of yield derivation for the Atlas model.

In the Maine ATLAS formulations, timberland acres were first stratified by ecological habitat as described in Appendix C. The second level of stratification was based on somewhat generic prescriptions, intending to reflect removal intensities (light, moderate, and regeneration harvests) and specific management regimes as described by data from both the 1995 resurvey and landowner information submitted to the Maine Forest Service. Currently, most of our statewide formulations have 27 secondary strata (management units in ATLAS terms), each of which contains plots (and subplots) from the resurvey data that represents acreage of Maine timberland.

For 21 of these strata, a volume class approach was used to circumvent the problem of deriving age for every FIA plot. Plots were assigned to volume specific groups that are separated by 10 years growth. All plots within a volume class were grown with the FlexFIBER model (30 years in 10 year increments) and the individual plot projections were averaged. The site index values associated with each of the FIBER ecological habitat types were used. The averages for the volume classes at time t, $t_{+10}$, $t_{+20}$, and $t_{+30}$ were then overlapped and averaged with volume classes adjacent to them. In the projection process, both overstory and understory trees down to 12" tall were used to identify individual species for ingrowth. If the species was not on the plot in the FIA resurvey it did not appear as future ingrowth. This was done to avoid assuming that previously recorded conifer species (1982 FIA resurvey) would automatically grow-in on stands currently in northern hardwood and aspen-birch FIA forest type groups that were assigned to the spruce-fir ecological habitat.

Strata representing high-yield practices: conifer plantations (black spruce, red pine, and larch), pre-commercial thinning of spruce-fir stands, and herbicide release (on spruce-fir and hemlock-red spruce ecological habitat types) were assigned yield curves differently. Due to a fairly limited history with these practices in Maine, the high-yield curves were built after a review of literature from the region (including maritime Canada) and private data solicited from industrial landowners. The curves were built by subjectively reducing the stocking percent from normal yield curves projected by the Growth and Yield model . The reductions were intended to produce curves representing the average yield expected in the 40 to 60 year age class (the expected economic rotation for high-yield silvicultural practices).

Yields in the ATLAS model are calculated by moving harvest acres down a yield curve to a designated residual volume, and the difference between initial volume and residual volume is harvest volume. This method assumes that harvested stands have the same growth qualities of younger stands. In our formulation, the pattern of how far down the yield curve to send acres conforms to our designations of light, moderate, or regeneration harvest management units. For example, in period 1 of the Base run, the light, moderate, and regeneration harvests in the spruce-fir ecological habitat averaged 8, 15, and 25 cords per acre respectively (at 85 cu.ft./cord).

Though we feel the current yield curves (sample in Table 1) and formulation are useful in providing meaningful results, we are currently working on refinements. Three of these are 1) partitioning plots in the oak/white pine management unit into oak and pine sub-units, 2)

incorporating a relative density measure into the existing volume class design, 3) making yield curves and model stratum that are more explicitly connected to different types of partial harvests.

One difficulties we experienced with the 1995 FIA data was due to the plot remeasurement interval varying from 12 to 16 years. Data with this long a remeasurement interval provides a somewhat fuzzy picture of the timing of specific harvest activity and the resulting growth response on individual plots. Another concern in defining more specific yield curves is the task of accurately estimating the acreage currently under specific management practices and dealing with the variability associated with a decreasing sample size. The implementation of an annual inventory will provide better resolution for assessment of harvest practices and associated yield curves. Future work should include an analysis similar to a recently published study in West Virginia that used a decision tree to classify harvests based on pre-harvest and post-harvest stand characteristics. (Fajvan, Grushecky and Hassler 1998). The discrete classifications were scored and validated with multiple discriminant analysis. These types of refinements would not require a different model or major changes to the existing stratification scheme, but would add refinement and insight to the existing formulation.

**Table 1. Examples of yield curves used in base run ATLAS formulation. Yield volumes are net merchantable cubic feet per acre.**

| | Years | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Yield Curve | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| Cedar/Black Spruce (Light Harvests) | 0 | 197 | 424 | 664 | 988 | 1349 | 1645 | 1897 | 2238 | 2508 | 2695 |
| Hemlock/Red Spruce (Moderate Harvests) | 0 | 232 | 409 | 685 | 1026 | 1331 | 1687 | 2054 | 2395 | 2697 | 2888 |
| Spruce-Fir (Regeneration Harvests) | 0 | 187 | 567 | 981 | 1422 | 1797 | 2195 | 2589 | 2921 | 3251 | 3610 |
| Beech/Red Maple (Light Harvests) | 0 | 236 | 475 | 821 | 1229 | 1559 | 1885 | 2192 | 2407 | 2605 | 2786 |
| Oak/White Pine (Moderate Harvests) | 0 | 256 | 466 | 721 | 988 | 1334 | 1667 | 1993 | 2430 | 2670 | 3034 |
| Sugar Maple/Ash (Regeneration Harvests) | 0 | 149 | 498 | 822 | 1262 | 1655 | 1952 | 2179 | 2355 | 2451 | 2370 |
| Spruce-Fir Herbicide Release | 0 | 0 | 45 | 629 | 1489 | 2429 | 2806 | 3106 | 3346 | 3539 | 3694 |
| Spruce/Fir PCT | 0 | 38 | 68 | 968 | 2336 | 3873 | 4537 | 5079 | 5079 | 5079 | 5079 |
| Black Spruce Plantation | 0 | 137 | 423 | 1469 | 2885 | 4223 | 4867 | 5395 | 6179 | 6467 | 6467 |
| Red Pine Plantation | 0 | 13 | 725 | 2336 | 4365 | 4733 | 6372 | 7406 | 8617 | 9094 | 9094 |
| Larch Plantation | 0 | 229 | 1137 | 3579 | 5823 | 7086 | 8136 | 9006 | 10317 | 10805 | 10805 |

## APPENDIX E. Identifying a theoretically ideal forest inventory level.

The concept of a single, idealized forest inventory has its roots in European "forest regulation", which is the scheduling of harvests to achieve the goal of perfect age class balance and even flow harvests. Nineteenth century European foresters believed that a forest with a balanced age class structure and a rotation age chosen to produce the biological maximum mean annual increment was an appropriate forest management goal. Stability and self-sufficiency with respect to wood production from the forest was the primary tenet, and long term harvest plans were developed to achieve these goals. Area control, volume control, area-volume check, and many other variants of forest regulation have been used to schedule harvests on forests during this century.

Today, most foresters in the United States accept that a strategic goal of a perfectly balanced forest is an overly simplistic objective. Nonetheless, a theoretically ideal forest structure and the inventory it represents can help non foresters understand the dynamics of a changing inventory.

In response to this educational need, a simple analysis calculated the statewide inventory volume, harvest, and growth if forest regulation was attained in Maine. Using the same regeneration harvest yield curves used in the ATLAS Base Run analysis, all timberland acres were allocated to single entry, even-aged management and long term, yield maximizing rotations (maximizing net cubic feet/acre/year not board feet/acre/year). Acres allocated to partial harvesting yield curves in the ATLAS Base Run were moved to the regeneration harvest management units within the same ecological habitat. All other strata were retained from the Base Run. High yield silviculture was allocated 1.063 million acres, the same as the second decade of the Base Run.

This analysis assumed that the yield curves used in the ATLAS Base Run are appropriate for continual rotations of regeneration harvest cuttings, that all timberland acres are operable and open to harvest, and that regeneration and stocking follow the yield curves exactly. Rotation age for Deer Winter Area's (DWA's) are set at 100 years, and only regeneration harvesting occurs on these acres.

Table 1 details the acreage allocated to ecological habitats, biological maximum rotation age calculated from the yield curves, and the change in growing stock inventory necessary to achieve "forest regulation". The results of this analysis indicate a "balanced" inventory of 17,407 million cubic feet and growth of 613 million cubic feet per year. The annual harvest on 265,278 acres yields a volume equal to growth, 613 million cubic feet. The average annual increment for the entire state under these assumptions would be 36 cubic feet/acre/year. These results support the hypothesis that the inventory of standing timber in Maine does not need to increase in order for net annual growth to increase.

**Table 1. Components of an idealized inventory for Maine.**

| Ecological habitats from ATLAS Base Run analysis | Acreage (M acres) | 1995 Inventory Volume (MM cu.ft.) | Idealized Inventory Volume (MM cu.ft.) | Rotation Length | Required inventory change for Regulation (MM cu.ft.) |
|---|---|---|---|---|---|
| Beech/Red Maple | 3,181 | 3,230 | 2,285 | 50 | -945 |
| Cedar/Black Spruce | 1,542 | 2,367 | 2,052 | 100 | -315 |
| Hemlock/Red Spruce | 1,252 | 1,923 | 1,449 | 80 | -474 |
| Oak/White Pine | 1,252 | 2,274 | 1,886 | 110 | -388 |
| Sugar Maple/Ash | 2,649 | 3,841 | 1,885 | 50 | -1,956 |
| Spruce/Fir | 5,836 | 7,822 | 6,647 | 70 | -1,175 |
| Precommercial Thinning | 324 | 2 | 346 | 50 | 344 |
| Herbicide Release | 407 | 0 | 275 | 50 | 275 |
| Larch Plantation | 19 | 1 | 37 | 40 | 36 |
| Pine Plantation | 102 | 101 | 134 | 40 | 33 |
| Spruce Plantation | 133 | 43 | 187 | 50 | 144 |
| Cedar/Bl. Spruce DWA | 57 | 93 | 76 | 100 | -17 |
| Hemlock/R. Spruce DWA | 33 | 63 | 48 | 100 | -15 |
| Spruce/Fir DWA | 165 | 215 | 100 | 100 | -115 |
| TOTALS | 16,952 | 21,975 | 17,407 | | -4,568 |